REPRES[illegible]STRIES IN THE [illegible]ATES

H. T. WARSHOW

American Business Series

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REPRESENTATIVE INDUSTRIES
IN THE
UNITED STATES

EDITED BY

H. T. WARSHOW

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To

ALLYN A. YOUNG

PREFACE

In order to grasp the significance of the advances in industry in recent years and to cope with the problems which accompany such rapid changes, it is essential to prepare a proper background by examining historically the development of individual industries and their growth in the nineteenth and twentieth centuries. Numerous books have been written by students and journalists tracing and interpreting the growth and development of industry in the United States; but the men who have helped to bring this development about, who understand its processes, and who are really an integral part of the development itself, have not as yet told their story. It is to these men — the leaders in industry — to whom we must look for the most competent exposition of the difficulties and growth of individual American industries. Economists and journalists may be better qualified to weave the raw material from such contributions into a general pattern; but for a specific and detailed analysis of his own business, it would seem that the best qualified person is the man who has spent his life in that business. Such is the theory upon which this volume is planned. The contributions follow a uniform outline and cover in a general way a brief history of the industry, the conditions surrounding its origin in the United States, its relation to American industry as a whole, the growth of its domestic trade, the improvements in technological processes, the growth of its export business, a discussion of its labor problems, a brief history of large consolidations or combinations, and any special developments peculiar to the individual industries. The volume does not pretend to cover all of the important industries in the United States. Its purpose is to include only a representative selection of manufacturing industries. In order to round out the volume, chapters have been added on building and banking, two industries which are related to all industries and on which they are all, in a general way, dependent.

The contents of this book may well appeal to the general reader of industrial and business problems; but in many cases, it is suffi-

ciently comprehensive to be useful to experts and specialists of the respective industries, or as a textbook in college courses in industrial organization.

A great many individuals and corporations have coöperated in the contribution of data and the opportunity is here taken to express my thanks and appreciation for the assistance rendered. I am especially indebted in a great many ways to Miss Frances Dublin and to my brother, Mr. Robert Irving Warshow.

H. T. Warshow

New York,
March, 1928.

CONTENTS

REPRESENTATIVE INDUSTRIES
IN THE UNITED STATES

CHAPTER I

THE ALUMINUM INDUSTRY

By ROBERT J. ANDERSON[1]

Introduction. The development of the aluminum industry, and more especially its rise in the United States, constitutes one of the most remarkable industrial romances in the history of the metals. Commercially, aluminum is a development of the twentieth century, and the greatest progress in the industrial use of the metal and its light alloys has come in the past twenty-five years. Only forty years ago, the aluminum industry, practically speaking, did not exist, and the metal was so prohibitively expensive that it could not be applied for commercial purposes. At the present time, aluminum is a direct competitor of copper and even of iron. In the present short discussion, it is possible to afford only a brief insight into the development and ramifications of the aluminum industry and to delineate its position in the United States with relation to other major industries. There is considerable fascination to the student of economics in tracing the rise of a great industry step by step, particularly when the expansion has been rapid. In the case of aluminum, the history is quite clear, mainly because a long time has not elapsed since the discovery of the metal.

Although aluminum is one of the most abundant metals of the earth's crust, it is at the same time one of the newest metals which has attained commercial importance. Aluminum can be produced readily only by methods involving modern electrometallurgical and chemical discoveries; hence the metal was entirely unknown until the early years of the nineteenth century. After its discovery, aluminum was slow in developing because of technical difficulties in extracting the metal from its minerals. Aluminum is the only commercial metal used in large tonnage, the ores of

[1] Consulting expert on aluminum.

which require expensive chemical treatment in order to produce a substantially pure compound before reduction. Iron, copper, lead, tin, and zinc can be readily made by direct carbon smelting from ores, and these metals were produced before the advent of modern science. The progress of aluminum has been extremely rapid in the past twenty-five years, but students of the industry feel that so far only a beginning has been made and that the future is one of great promise.

The subject of aluminum and its light alloys is one that opens up wide fields of importance to the metallurgist and engineer, while the utility of the metal is becoming more apparent to the layman. At the moment of writing, the aluminum industry is at a stage where very important advances have just been made, and others are expected shortly. These include not only technical advances in production, manufacturing, and utilization, but also facilities for additional output, as well as important economic developments, all of which have a cogent bearing on the immediate future.

As is well known, the aluminum industry has been shrouded in silence and mystery for many years, evidently due to misunderstandings which arose in the early days between different producers. At any rate, the leading producers adopted the policy of refusing to give out production statistics and other important information regarding their operations. Since the World War, considerable knowledge regarding aluminum has been made available, in part due to a more enlightened policy on the part of some producers, in part due to governmental investigations of the facts bearing on aluminum tariffs and monopoly, and in part due to many technical studies of the metal and its alloys by numerous scientific investigators. The discussions in the daily newspapers in recent years regarding tariff, competition, litigation, and monopoly, which have centered around the Aluminum Co. of America, have naturally served to stimulate general interest. Owing in part to the use of the metal and its light alloys in aircraft and automotive construction, as well as for various household appliances, considerable public interest has been aroused in the past fifteen years. Aluminum is now a familiar metal to the layman.

Aluminum is the lightest of the commercial metals which are used in large quantities, having specific gravity of 2.7, as against about 8.9 for copper and about 7.8 for mild steel. Thus, 1 cubic

foot of aluminum weighs only 169 lbs., as compared with 556 lbs. for copper, and 487 lbs. for steel. Once obtained in the form of pig metal by the modern reduction process, aluminum can be cast, worked, alloyed, and fabricated with moderate ease. Metallurgically, it is one of the most interesting metals, while from the point of view of utility its applications are legion. The merits of aluminum and its light alloys have been forced upon the engineering trades against a not inconsiderable opposition and necessarily in competition with older and better known materials. At the present time, the light alloys have been subjected to a degree of scientific study which is doubtless now unequaled for any other construction materials. The actual worth of the metal and its light alloys for use as engineering materials of construction has been proved beyond any doubt. In the past ten years, the value of systematic research in improving the properties of aluminum alloys and in finding new fields of usefulness has been conclusively demonstrated. Aluminum has now established a place for itself among the non-ferrous metals by virtue of its intrinsic worth, and even despite its relatively high price its consumption is increasing yearly at a rapid rate.

As will be explained more fully in later paragraphs, aluminum is reduced by an electrolytic process from substantially pure aluminum oxide, this latter having previously been prepared by a chemical method from bauxite (the ore of aluminum). For the electrolytic process, a primary requisite for commercial operation is a source of cheap electric current. Hence, practically all aluminum-reduction plants in the world consume electric energy derived from hydroelectric power plants. Aluminum-reduction plants are normally situated within easy access of water falls, and steam-generated electric current is totally out of the question for economical aluminum production. Recent expansion of the aluminum-reduction capacity of the world has been toward countries like Canada and Norway, which possess good water powers and are not too remote from the aluminum-consuming markets. Water powers near to ocean shipping are especially desirable as locations for aluminum-reduction plants. The political control of both the world's bauxite mines and aluminum-reduction works is largely in the hands of the United States, Great Britain, France, Germany, and Switzerland. Several of the large aluminum-producing companies are international in scope, mining bauxite

in one country, treating ore for the preparation of aluminum oxide in another country, reducing the metal in the same (or still another) country, while marketing the bulk of their output either at home or abroad. The aluminum industry of the United States (if not of the world) centers around the Aluminum Co. of America, a powerful organization of international scope, rated at $250,000,000. Hence, in discussing the domestic aluminum industry here, it will be necessary to deal at some length with the foreign ramifications.

In a restricted space, it is obviously no easy task to write anything satisfactory on the industrial development of aluminum which will tell the whole story, touching upon the past, present, and future. In the present discussion, it will be possible to mention only the more outstanding and interesting industrial and technical developments of the aluminum industry. The technical metallurgy of aluminum is discussed at length in the writer's book, "The Metallurgy of Aluminum and Aluminum Alloys."[1] Aluminum celebrated the centennial of its discovery in 1925, while the early beginnings of the industry date back only to the middle of the nineteenth century. This period will live in history as the century which gave to the world the railroad, telegraph, telephone, bessemer steel, dynamo, and aluminum.

Historical Survey. Aluminum, as a metal, cannot lay claim to great antiquity, as contrasted with iron, copper, and copper alloys, and it was a rare metal as late as 1850. The origin of the word aluminum is traced back to Pliny, who used the term *alumen* for the name of certain salts used in dyeing. Evidently, this alumen was a mixture of aluminum sulphate with iron sulphate. Why this material was termed alumen is not known, but it may have been derived from lumen (light) in allusion to its brightening the colors when used in dyeing. As early as the middle of the eighteenth century chemists suspected that ordinary clays and alums had a metallic base, and numerous attempts were made to isolate the suspected base of these materials. In 1809, Sir Humphrey Davy fused iron in the electric arc in contact with alumina (aluminum oxide) and obtained an iron-aluminum alloy, thus proving that the oxide could be decomposed and its metal obtained. The attempts of early investigators to produce aluminum are described at length in some of the older text books.[2]

[1] Henry Carey Baird and Co., New York, 1925, 913 + pp.

[2] *Vide* Richards and Minet, appended bibliography.

Aluminum was first isolated in 1825 by the Danish chemist Oersted, who reduced aluminum chloride with potassium amalgam. The discovery of the metal is often attributed to the German chemist Wöhler, who, in 1827, reduced aluminum chloride with potassium. However, certain documentary evidence has recently come to light which apparently shows that Oersted prepared the first aluminum. It is to Henri St. Claire Deville, of Paris, France, that the honor belongs of having isolated aluminum in fairly large quantities in 1854, and civilization is indebted to this eminent chemist for the pioneer work on reduction process for the production of the metal. Deville first made aluminum by the reduction of its chloride, with potassium, and later improved upon Wöhler's earlier methods and used sodium instead of potassium, thus producing the metal at less cost. He also worked with aluminum-sodium chloride, which is more suitable than aluminum chloride. Deville also perfected processes for the manufacture of sodium, which greatly reduced the price of both sodium and aluminum. However, the Deville processes were all expensive and not adapted to the cheap production of aluminum in large tonnages. In 1852, before Deville's work, the price of aluminum was somewhat over $500 per lb., and he gradually reduced this to about $11, this latter price holding until about 1886. The great hopes of Deville for the establishment of the aluminum industry were never realized, little progress being made until 1886. However, it was due to Deville's genius that the aluminum industry was actually started. In 1886, H. Y. Castner of New York developed a process for the manufacture of sodium, reducing the cost of sodium from $1 to about 25 cents per pound. This process was employed for several years in making sodium for use in the reduction of aluminum chloride made by the Webster process, and the selling price of aluminum was reduced to about $4 per pound in 1888.

In 1886, A. H. and E. H. Cowles of Cleveland, Ohio, patented a process for the reduction of alumina by carbon in the presence of a metal (*e.g.*, copper). Intermediate aluminum alloys were produced by this process. The Cowles brothers were early pioneers in aluminum metallurgy and great credit is due them for research work which formed the basis of the present modern reduction method. In 1886, Charles M. Hall of Oberlin, Ohio, found that alumina dissolved in a fused bath of aluminum fluoride and the

fluoride of another metal formed an electrolyte which could be decomposed by the electric current and yield aluminum. At about the same time, a similar discovery was made by P. L. T. Héroult in France. Hall's original patent was applied for July 9, 1886, and granted April 2, 1889. A patent covering the reduction of aluminous compounds by the electric current had been applied for by C. S. Bradley on February 23, 1883, but was not granted until February 2, 1892. All of the Bradley patents were taken over by the Cowles brothers in 1885, and this particular patent was made the basis for long and bitter litigation between the Electric Smelting and Aluminum Co. (the Cowles concern) and the Pittsburgh Reduction Co. (the Hall concern — later the Aluminum Co. of America). According to the final court decision it was held that the principle of the Bradley patent was infringed by the Pittsburgh Reduction Co. and that Hall had simply added improvements to the Bradley process. It is still maintained by the Cowles interests that their knowledge of aluminum reduction was taken bodily by Hall (after his employment in their plant during 1887–1888) and used as a basis for promoting the Pittsburgh Reduction Co. As a result of the litigation, the Hall company paid damages and royalties to the Cowles company until the expiration of the Bradley patent. The present successful aluminum-reduction process is usually referred to as the Hall-Héroult process, and due credit must be given Hall for the commercial development of aluminum. This process, as based on the Bradley-Hall-Héroult inventions, caused a revolution in the aluminum industry, and modern aluminum metallurgy really dates from about 1890. The effect of this process on the price of aluminum was felt shortly after 1888; by 1892, the price was 60 cents per pound and all other processes had been driven from the field. The history of the development of the aluminum industry of the United States from 1899 to date is largely a history of the Aluminum Co. of America, which is traced in later paragraphs.

In summing up the history of development in the aluminum industry, the progress may be divided, for convenience, into five transition periods:

(1) The period of time dating from the discovery of the metal by Oersted in 1825 to the invention of the Hall-Héroult process in 1886–1888. During this time, investigations were made by a long list of workers with a view to devising processes for the com-

mercial production of aluminum. Progress was necessarily slow. This period covered about sixty years.

(2) The period dating from the invention of a cheap commercial process for the electrometallurgical reduction of aluminum, indirectly from bauxite, until the difficulties incident to the process had been largely overcome and the industrial importance of the metal for particular purposes had been proved. This period covered about ten years (from 1888 to 1898), and during this time producers were engaged chiefly in technical problems, raising capital and finding outlets for their product.

(3) The period after the commercial manufacture of the metal had been worked out satisfactorily and the importance of the metal established until the domestic automobile industry commenced large-scale production. This period covered about ten years (from 1898 to 1908), and during this time aluminum producers were engaged in making plant extensions, acquiring bauxite reserves, finding new outlets for the metal and increasing its applications, and establishing themselves in the electrical field — where they introduced aluminum wire for the transmission of electric current in competition with copper.

(4) The period dating from the manufacture of automobiles on a large scale until the end of the World War. This period covered about ten years (from 1908 to 1918), and witnessed a great rise in the consumption of aluminum for many old purposes, while many new uses were developed. The rapid expansion of the domestic automotive industry was accompanied by the production and consumption of aluminum on a greatly enlarged scale due to the widespread use of the metal and its alloys as construction materials in motor cars. Aluminum had rapidly extended its field of usefulness prior to the World War, but that event was the cause of unprecedented interest in its properties, uses, and alloys.

(5) The period dating from the end of the War to the present date. This period has witnessed a revolution in the development and uses of the metal and its light alloys, and the resultant broadening of the market has markedly altered the outlook for the metal. The development of heat-treatment processes for enhancing the mechanical properties of various new and special aluminum alloys has resulted in the production of aluminum alloys with properties which far exceed anything obtainable even a few years ago. No metal has received more scientific attention in the past ten years

than aluminum, and the developments made recently indicate that great progress may be looked for in the future.

Aluminum Ores and Bauxite Production. Aluminum is the most abundant of the industrial metals and is third in abundance of the elements in the earth's crust, following oxygen and silicon. It is nearly twice as abundant as iron and constitutes about 8 per cent of the earth's crust. Aluminum is an essential constituent of all important rocks except the sandstones and limestones, but even in these its compounds are common impurities. The metal never occurs native; except for its fluorides, it invariably occurs as oxidized compounds. Thus, it is found mainly in the silicates, such as the clays, micas, and feldspars; as the oxide, corundum; as the hydroxide, bauxite; as the fluoride, in cryolite; and also as various phosphates and sulphates. Although aluminum minerals occur widely, few of these can be employed as ores in the reduction of the metal, and in the present commercial production of aluminum only two aluminum minerals find use: bauxite and cryolite. Bauxite is the base ore for aluminum reduction and bears the same relation to aluminum that hematite does to iron. Cryolite is the basis of the reduction-cell bath.

The chief minerals of aluminum include the following: bauxite, gibbsite, diaspore, cryolite, alunite, corundum, laterite, feldspars, kaolin, sillimanite (and related minerals), alunogen, turquois, chrysoberyl, spinel, and topaz. Bauxite takes its name from the village of Baux, near Arles in France, where it was first found by Berthier. Bauxite occurs at a number of places in the world, but high-grade deposits are not numerous. Commercial bauxite is an hydrated oxide of aluminum, or a mixture of at least two and probably three hydrates, mixed with various impurities, chiefly iron oxide, silica, titania, and clay. The water content is variable over a wide range. In a general way, the range of composition of bauxites is as follows: alumina, 45 to 70 per cent; silica, 2 to 30 per cent; iron oxide, 3 to 25 per cent; and loss on ignition, 12 to 40 per cent. Bauxites may be roughly classified as follows on the basis of their impurities: (1) high in iron and low in silica (red varieties); (2) low in iron and high in silica (white and gray); and (3) iron and silica contents about the same, either high or low. Bauxite is graded according to chemical composition and used by the consuming industries on the basis of chemical analysis. Bauxite for aluminum production should contain not less than 52 per cent

alumina, not more than 4.5 per cent silica, and not more than 6.5 per cent ferric oxide. High-grade bauxites for aluminum manufacture often contain 58 to 65 per cent alumina, as little as 1 per cent ferric oxide, and 3 to 5 per cent silica.

Bauxite Deposits of the World. The principal bauxite deposits of the world are owned by the large aluminum-producing companies. In 1926, the largest producing mines were those of France, the United States, British and Dutch Guiana, Istria (Italy), and Yugo-Slavia. Other present producing countries include Austria, India, Germany, Rumania, Spain, and the United Kingdom. Bauxite deposits are known also in French Guiana, Australia, Brazil, Venezuela, Africa (notably in the Gold Coast), Hungary, and Russia. The principal bauxite-producing field of the United States is that of Arkansas, while fields of less importance are in the states of Alabama, Georgia, and Tennessee. Occurrences of bauxite are also known in Mississippi, California, South Dakota, Colorado, New Mexico, South Carolina, and Wyoming. Bauxite was discovered in the United States in 1887, a few miles north of Rome in Floyd county, Georgia, and shipments were made from that point in 1889. In 1891, shipments began from Alabama, and about that time large deposits were found in Arkansas. The first shipment was made from Arkansas in 1900 and from the Tennessee deposits in 1907.

Practically all of the bauxite deposits in the United States having commercial value are controlled by the Aluminum Co. of America. Its subsidiaries, the American Bauxite Co. and the Republic Mining and Mfg. Co., are the principal bauxite producers in the country. In British Guiana, the bauxite deposits are extensive and of good quality; they are owned largely by the Demarara Bauxite Co., a subsidiary of the Aluminum Co. of Canada, Ltd., in turn a subsidiary of the Aluminum Co. of America. These deposits are the largest in the world accessible to ocean shipping, and it is expected that they will play a prominent part in the world's aluminum industry. Bauxite mines are worked in the Dutch Guiana colony of Surinam by the Surinaamsche Bauxite Maatschappij, a subsidiary of the Aluminum Co. of America. The French bauxite deposits are the richest and largest in the world, available reserves indicating no exhaustion in 100 years with even double the present production. These deposits occur in the southern part of the country in a band almost parallel to the Mediterranean Sea. The

French bauxite mines are now largely controlled by L'Aluminium Français, through subsidiaries. The British Aluminium Co., Ltd., and the Aluminum Co. of America also have holdings in France. German bauxite deposits are poor, and the production is small. India contains workable bauxite deposits, but production to date, has been small because there is no local consumption and any tonnage mined must be shipped long distances to consuming markets in competition with ores from nearer sources. As a result of the World War peace treaty, Italy acquired rich bauxite lands along the Adriatic Sea in Istria from Austria, while Yugo-Slavia acquired the fields in Dalmatia, Herzegovina, and Montenegro. Bauxite occurs in the Gold Coast and Nyasaland, but the deposits have not yet been exploited. The estimated quantity available is in excess of 50,000,000 tons of good-grade ore, and when transport facilities are extended and freight charges reduced, these deposits will be exploited with profitable results.

The world's resources of bauxite are ample to insure substantial increase in mining production for some time to come, but unless new fields are opened and further discoveries made, or unless some of the present remote and unexploited deposits are developed, unlimited tonnages of bauxite cannot be expected to be taken out. Total known reserves of bauxite have been enhanced recently by the exploitation of new fields and the discovery of additional deposits. The most important of the recently exploited fields are those in the South American Guianas, while the best of the newly discovered deposits are those in Africa (the Gold Coast).

The only commercial source of cryolite is the famous deposit at Ivigtuk, Araukfiord, South Greenland, owned by the Kryolith Mine and Handelsskabet A/S of Copenhagen, Denmark. The import rights for cryolite from this deposit into the United States are held by the Pennsylvania Salt Mfg. Co.

Bauxite Production and Markets. In 1925, the leading bauxite-producing countries were the following: France (405,000 metric tons), the United States (321,622), British Guiana (200,000), Italy (198,000), Dutch Guiana (100,000), Yugo-Slavia (65,000), and India (25,000). Total world production of bauxite in 1925 was about 1,338,000 metric tons, as against 1,065,000 tons in 1924. In 1900, the total world production of bauxite was a little less than 100,000 tons. Preliminary figures indicate that the world production in 1926 was the largest on record, totaling about 1,475,000

metric tons. In the early years of the aluminum industry, France was the leading producer of bauxite, but the United States took the lead in 1914. In 1925, France again attained her former

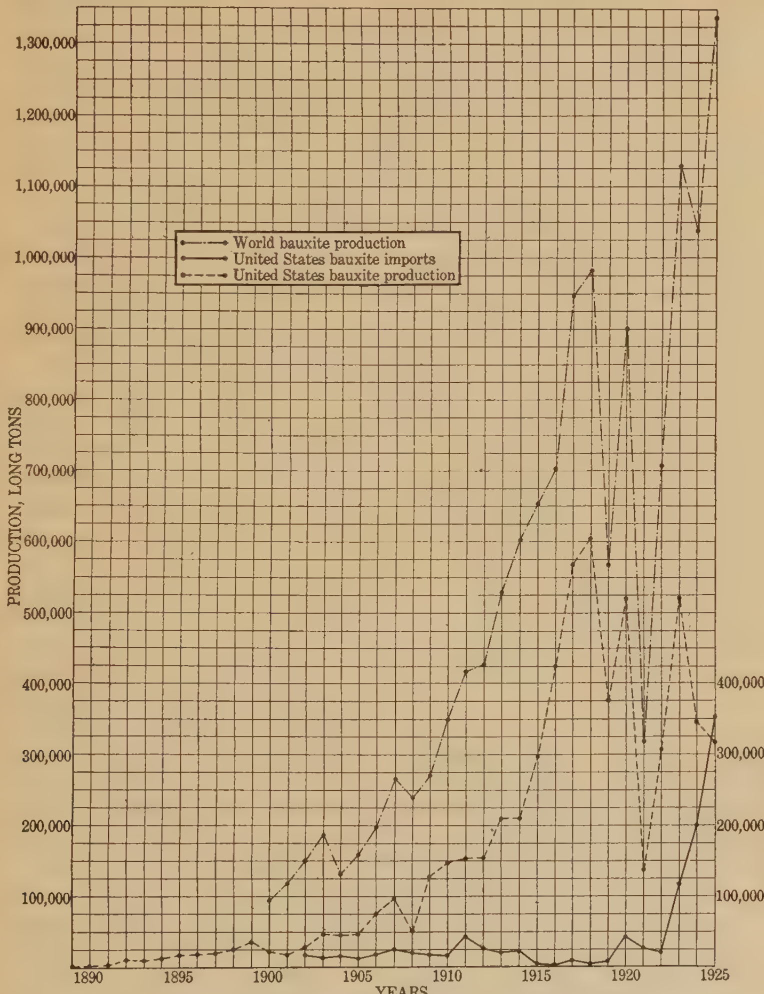

FIG. 1.—World production, United States imports, and United States output of bauxite over a period of years to the end of 1925.

position as the foremost bauxite-producing country of the world. Bauxite production in the United States is declining, owing to the fact that foreign ores (chiefly from South America) can be brought

to American consuming points at lower cost than the domestic ores can be mined. Evidently, the present policy of the Aluminum Co. of America is to decrease gradually its Arkansas operations and increase output in the Guianas. The general depression in the world's aluminum industry after the War caused a great slump in the bauxite-mining end. Total world output of bauxite fell off from 962,876 metric tons in 1918 to 330,146 tons in 1921. In the past five years, however, the output has increased markedly. Table 1 shows the world production of bauxite by the leading countries over a period of years (Mineral Industry statistics). Figure 1 shows the total world production of bauxite, United States output, and United States imports over a period of years.

The total imports of bauxite into the United States in 1925 were 353,696 long tons, valued at $1,549,120, as compared with 201,974 tons, valued at $909,493 in 1924. Little bauxite ore is exported from the United States, but about 75,000 to 80,000 tons of alumina is being exported yearly, chiefly to foreign reduction works of the Aluminum Co. of America. Imports of bauxite into the United States come largely from British and Dutch Guiana, Yugo-Slavia (Dalmatia), and Istria (Italy), with lesser amounts from France. Germany is a large importer of bauxite, chiefly from continental European sources.

The market for bauxite is rather restricted since consumers either largely control their own supplies or else are covered on long-time contracts with mines. In 1926, domestic crushed and dried bauxite sold in the United States at $5.50 to $8.50 per gross ton, f.o.b. shipping point; the pulverized and dried ore was $14; and crushed and calcined ore sold at $17 to $20. Dutch Guiana ore was offered at $8.50 per long ton, c.i.f. New York, Dalmatian ore at $5.50 to $6.50, Istrian at $5.50 to $7, and French red ore at $6 to $7.50. Calcined alumina sells at about 6 cents per pound.

Bauxite Mining and Preparation. Bauxite has been mined in the past largely by open-pit methods since deposits are normally found as outcrops and lie near the surface. In mining, the overburden is first stripped off with steam shovels or small scrapers, and the stripped surface is then cleaned and swept. While the ore is often loosely consolidated, it may be too hard to be mined without first breaking up by blasting. This latter is done with low-strength dynamite. In large-scale operations, the loosened ore is loaded by steam shovel on to small railroad cars, and hauled out.

TABLE 1

WORLD PRODUCTION OF BAUXITE

(In metric tons)

COUNTRY	1913	1920	1921	1922	1923	1924	1925
Austria	[a]	362	2,638	4,095	2,734	[b]3,000	[b]4,000
British Guiana	1,999	31,883	[f]	[f]	135,712	188,071	[b]200,000
British India	1,709	6,401	6,759	4,998	6,652	23,602	[b]25,000
Dutch Guiana				18,805	15,839	[b]60,000	[b]100,000
France	159,103	266,716	95,318	236,141	314,330	335,582	405,000
Germany	9,393	13,420	10,122	15,146	6,662	[b]10,000	[b]6,000
Hungary	[c]	[c]	[c]	[c]	[c]	[c]	[c]
Italy	2,972	[e]13,139	[e]49,120	[e]66,646	[e]98,055	[e]145,520	198,000
Rumania	[d]	[d]	[d]	3,737	4,162	[b]5,000	[b]7,000
Spain	1,780	540	184				
United Kingdom	9,369	11,197	2,305	5,953	3,504	5,241	[b]7,000
United States	382,610	529,675	141,790	314,569	531,079	352,117	321,622
Jugo-Slavia	[c]	27,860	10,021	31,290	32,631	[b]37,000	[b]65,000
Total	568,935	901,193	318,257	701,380	1,151,360	1,065,133	1,338,622

[a] No record of any production prior to 1920 for lower Austria; output of Dalmatia and Istria prior to 1919 given under Austria in most statistical tables (cf. volumes of The Mineral Industry). Starting with 1920, figures for Dalmatia are given under Yugo-Slavia, and those for Istria under Italy. [b] Estimated. [c] Data not available.

[d] The bauxite deposits in the Bihar Mountains in Rumania were not exploited until the World War, when they were owned by Hungary. [e] Istria included under Italy.

[f] The bauxite mines were closed early in 1921, and operations did not begin again until late in 1922. Shipment of 20,010 tons was made from stocks in 1921, and no shipments made in 1922.

Figure 2 shows the mining of bauxite with steam shovel at a mine of the American Bauxite Co., Bauxite, Ark. Recently, underground mining has been started at several deposits both here and abroad in order to overcome heavy stripping costs.

Bauxite, when mined, may be given preliminary treatment on the ground, depending on the nature of the ore. The bauxites found in the United States normally contain from 15 to 33 per cent

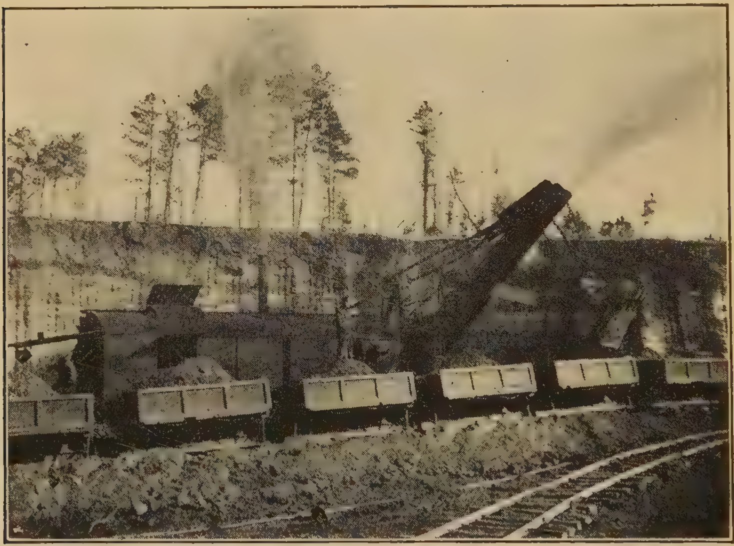

FIG. 2.—View showing bauxite mining with steam shovel at mine of the American Bauxite Co.

of combined water, and since the ores must ordinarily be shipped long distances, it is usual to dry the ore at the mines so as to save freight and also to facilitate fine grinding for later use. For the preparation of alumina to be used in the reduction of aluminum, bauxite is ordinarily crushed and dried at the mine but not ground finely. It is desirable to calcine most bauxites in order to remove organic matter, but some bauxites are directly amenable to wet chemical treatment after fine grinding without pre-calcination. Crude undried bauxite may be shipped in any type of railroad car, but dried or calcined ore is usually shipped in bulk in box cars or in special closed-top hopper-bottom cars.

The rapid increase in the production of aluminum and the approaching exhaustion of certain present production deposits

emphasize the need for methods of utilizing the low-grade bauxites. Recently, considerable interest has been displayed in the question of beneficiating or concentrating low-grade bauxites and bauxitic clays. Beneficiating treatment might make it possible to recover bauxite from two types of ore not hitherto of commercial value: (1) deposits carrying both high-grade bauxite and clay; (2) deposits of low-grade bauxites and bauxitic clays. Although some processes have been developed, none of these seems to be commercial, and there is great need for a cheap process that can be applied for the beneficiation of low-grade bauxites.

Uses of Bauxite. The present principal uses of bauxite are the following: (1) for the preparation of alumina to be used in the reduction of aluminum; (2) for abrasives manufacture, *e.g.*, artificial abrasives like alundum; (3) for aluminum-salt preparation, including alum, aluminum sulphate, and aluminum chloride; (4) for refractories manufacture, although bauxite is being largely supplanted by diaspore and the bauxitic clays; (5) for aluminous-cement manufacture; and (6) for petroleum refining. There may also be added the use of bauxite in the manufacture of calcium aluminate to give a quick set to plaster compositions. In former years, an average of about 80 per cent of the bauxite mined went into aluminum reduction. This ratio is changing with the increased and enlarged uses of the mineral, and at the present time only about 65 per cent of the bauxite output is being used for aluminum production.

The development of the aluminous-cement industry has greatly increased the demand for certain types of bauxite, notably in France. This development has gradually spread to other countries, and if the growth continues, there may be an actual shortage of suitable bauxites. French production of aluminous cement is now about 500,000 bbls. per annum, equivalent to about 83,000 long tons, or about one eighth of the output of Portland cement. The world output of Portland cement is running at the rate of 420,000,000 bbls. per annum, equivalent to 70,000,000 long tons. If 10 per cent of this were converted to aluminous cement, and there is ample scope for this production, the amount of bauxite required in making it would be about 3,500,000 tons. Thus there may easily be caused an acute shortage of bauxite. French producers have, indeed, been pinched for supplies recently. Aluminous cement is now being made in small production in the United States.

Aluminum sulphate is used largely in paper making for sizing, as a mordant in dyeing, for water purification, in tanning, and for deodorizing and decolorizing mineral oils. Aluminum chloride is used in oil refining, for carbonizing wool, and in the manufacture of certain organic compounds. While aluminum chloride is being used considerably in oil cracking, the cost is high, as compared with the simple heat and pressure processes. The quality of the gasoline produced by the aluminum-chloride process is excellent, but the method has limitations. According to calculations, if 1,000,000,000 gals. of cracked gasoline were produced by the aluminum-chloride process, some 1,500,000,000 lbs. of the salt would be required.

Production of Aluminum. For the past 37 years, the production of metallic aluminum on a commercial scale has been carried out in two essential steps; (1) the preparation of alumina of high purity from bauxite; (2) the electrolysis of the alumina in a liquid (molten) bath of cryolite plus other added salts. The reduction of alumina to aluminum cannot be done commercially by carbon smelting, as with iron, copper, lead, zinc, and other commercial metals. Or, more precisely, alumina can actually be reduced to aluminum by carbon, but at the temperature and under the conditions of such reduction, the aluminum reduced either volatilizes, oxidizes, or carburizes. The electrometallurgical process employed in the electrolytic dissociation of alumina is that described in the Bradley-Hall-Héroult patents of 1883–1892. Of course, various technical improvements have been made in the past 35 years, but the principle of the process has remained the same. Good aluminum can be made only from pure materials, and the first step in the modern process calls for the preparation of substantially pure alumina.

It should be emphasized that one of the chief difficulties hitherto in the metallurgy of aluminum has been owing to the fact that the metal, after being produced, cannot be refined as can copper and other of the commercial metals, and the purity of the metal secured depends upon the purity of the alumina used, that of the carbon electrodes, and of the electrolytic bath. As will be explained under the caption Metallurgical Progress, below, the Hoopes process has been recently devised which provides for the refining of impure aluminum, but this is not yet on a commercial basis. Many patents have been issued which apparently cover every conceivable method of obtaining aluminum from aluminous

minerals, but the only commercial process is that one calling for the electrolytic dissociation of alumina dissolved in a liquid bath of cryolite plus other added salts. The dream of many a chemist is the cheap production of aluminum by direct smelting from low-grade clays, which occur in great abundance. If such a process is ever developed, and in the light of recent research this appears to be possible, it will mean another revolution in the aluminum industry. Electrolytic methods for the dissociation of aluminum compounds are not applicable in aqueous solution, and fused electrolytes must be employed.

In the present Hall-Héroult process, the raw materials for aluminum reduction include substantially pure alumina, cryolite (plus calcium and aluminum fluorides for the bath), and carbon electrodes. The first step in the manufacture of the metal consists in the purification of bauxite, whereby substantially pure alumina is produced.

Preparation of Alumina. As pointed out previously, crude bauxite ore contains varying amounts of ferric oxide, silica, titania, and other impurities. These substances should not be present in the alumina which is added to the reduction-cell bath, since otherwise the reduced metals from the impurities would appear in the resultant aluminum. The usual process for the preparation of alumina from bauxite is the Bayer process, a wet chemical method. The present high price of aluminum is in part due to the costly wet chemical treatment required for the bauxite. In the Bayer process, calcined bauxite is ground and then treated with sodium-hydroxide solution. By the chemical action involved, the alumina of the bauxite is dissolved as sodium aluminate, and this latter is filtered from the impurities which are left unattacked. Aluminum hydroxide is then precipitated from the filtered solution, and after filter-pressing the partly dried hydroxide is calcined in rotary kilns to drive off water and yield substantially pure alumina. In the Bayer process, the various steps must be carried out under definite conditions and with proper control in order to secure efficiency. The more technical aspects of the process cannot be taken up here. The alumina derived from the Bayer process is fed directly to reduction cells for the production of aluminum.

In passing, it may be stated that numerous processes have been devised for extracting alumina from clay and other aluminous

minerals, most of these methods involving digestion with acids, followed by decomposition and precipitation of the salts formed. None of these processes has been able to compete with the Bayer process. So far, the electric smelting of bauxite to yield alumina has not been a factor in the industry, but the Haglund process[1] recently developed abroad is to be worked commercially, and this appears to have great possibilities. The preparation of alumina from bauxite is a great chemical industry in itself. The alumina plant of the Aluminum Co. of America at East St. Louis, Ill., produces over 400,000,000 lbs. of alumina annually.

Production of Primary Aluminum. Essentially, the electrolytic dissociation of alumina is quite simple. It consists in passing a direct current of low potential through a fused bath of cryolite in which pure alumina has been dissolved. On passage of the current, the aluminum is liberated and accumulates at the bottom of the bath, while the oxygen goes to the carbon anodes and burns. In the process, the electric current serves two important functions: (1) it keeps the electrolytic bath liquid by the generation of heat; (2) it causes electrolytic dissociation of the alumina. Theoretically, the decomposition voltage required is 2.8, but in practice about three times this is actually used. The electrolysis is carried out in a carbon-lined furnace or cell, the carbon lining serving as the cathode and separate carbon electrodes as the anodes. The composition of the electrolytic bath is especially important, and the actual compositions employed in practice vary somewhat among different producers. Both natural and artificial cryolite are used as the basis of the bath, and to this may be added fluorspar or other fluorides to reduce the melting point. The alumina content of the bath is controlled by suitable appliances, and fresh alumina is charged as required.

The usual aluminum cell consists of a rectangular box of mild steel, lined with a refractory material of low thermal and electrical conductivity, and within this a heavier lining of rammed carbon forming the cathode. The bottom is inclined toward the tap hole, and each anode is arranged so that it can be operated independently of the others. Aluminum furnaces are built in various sizes, *e.g.*, 8 ft. long by 4 to 5 ft. wide by 2 ft. high. Figure 3 shows a sketch of a typical aluminum-reduction cell. Usually 30 to 40 cells are connected together in series, since it is not yet economical

[1] *Vide* Metallurgical Progress, below.

to build dynamo-generators of the low voltage required. Aluminum is tapped from the furnaces every day or so, and this metal is remelted and cast into pigs and ingots, forming the raw aluminum of commerce. Roughly, 2 lbs. of alumina and 1 lb. of carbon anode are consumed per pound of aluminum produced. Theoretically, it requires only about 5 kilowatt-hours to electrolyze 1 lb. of aluminum out of the bath, but the usual power consumption is

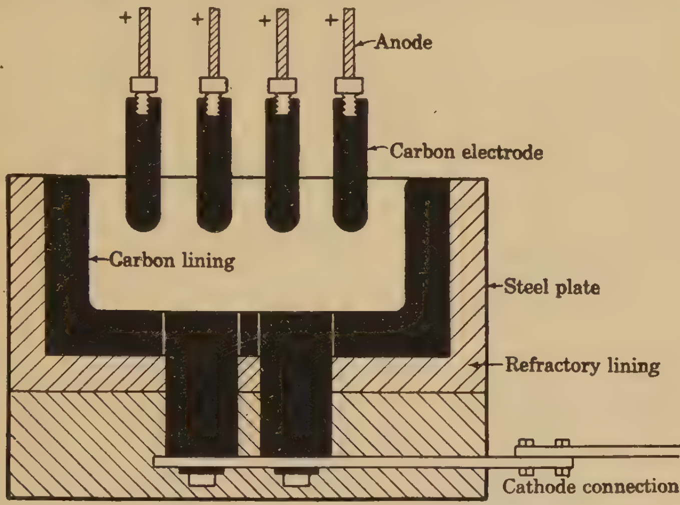

Fig. 3.—Sketch showing construction of typical aluminum-reduction cell.

12.5–13 kilowatt-hours. The present world production of aluminum requires about 800,000 horsepower. The principal items entering into the production cost of aluminum include the following: electrical energy, bauxite, chemicals for preparing alumina, cryolite, carbon electrodes, fuel, labor, supervision, maintenance, transportation, and interest on investment. Aluminum production cost averages about 12–13 cents per pound.

Since the anodes come into direct contact with the bath, they must be as free as possible from impurities, and the manufacture of high quality electrodes is an important part of modern aluminum production. Petroleum coke is the usual material employed for making these electrodes. The Aluminum Co. of America consumes about 200,000,000 lbs. of carbon anodes per annum in its operations in the United States. The Söderberg continuous electrode has lately been tried in aluminum furnaces.

The product of the reduction cell, after remelting to remove occluded bath material, appears on the market as primary aluminum, and this is graded according to the amounts of impurities present. The chief impurities are copper, iron, and silicon. Ordinarily, three grades of primary aluminum are marketed: (1) special, containing 99.5 per cent aluminum; (2) grade No. 1 (or grade A), containing 99+ per cent aluminum; and (3) grade No. 2 (or grade B), containing 98–99 per cent aluminum. Primary aluminum alloys are made by a remelting operation in which an alloying metal is added to primary aluminum. In 99+ per cent metal, the content of impurities is usually as follows: copper, 0 to 0.10 per cent; iron 0.25 to 0.40 per cent; and silicon, 0.20 to 0.40 per cent. Primary aluminum pig appears on the market in different forms which vary among the producers, *e.g.*, three-notch 33-pound pigs and small notch bars weighing about 3 lbs.

Secondary Aluminum. The metal made in the reduction cell is termed primary aluminum to distinguish it from secondary aluminum made by the remelting of scrap. The production of aluminum and aluminum alloys in pig form from scrap aluminum and alloys of various kinds has grown to be a large and important branch of the American aluminum industry. In 1913, the first year for which statistics are available, 9,308,000 lbs. of aluminum (either as such or in the form of alloys) were recovered by secondary smelters in the United States. This amount of metal was valued at $2,199,480. In 1926, the quantity recovered was about 100,000,000 lbs. with a value of about $23,000,000. The secondary recovery is now about half of the total production of new metal in this country. The chief aluminum and alloy scraps and wastes available in the market to the secondary smelter include the following: (1) drosses and skimmings; (2) borings and similar machining scrap; (3) heavy castings scrap; (4) fabricating scrap; and (5) miscellaneous scrap. A large tonnage of scrap arises yearly from the wrecking of old motor cars. About 1,000,000 old cars are being demolished annually in the United States, and figuring an average of 40 lbs. of aluminum and aluminum alloys per car, about 40,000,000 lbs. of scrap would arise yearly from this source.

The work of the secondary aluminum smelter consists in the purchase of all kinds of aluminum and alloy scrap and wastes and the conversion of these into saleable products by proper treatment,

blending, and furnacing. Unlike copper or lead drosses and residues, aluminum and aluminum-alloy drosses cannot be treated by a primary process, *i.e.*, they cannot be smelted with coke and reduced or introduced into electrolytic cells. Hence the smelting of aluminum and alloy drosses and residues differs from the treatment of most other metal drosses in that only free metal can be liberated, the oxide being simply separated. Secondary aluminum and aluminum-alloy pig are not necessarily inferior in quality to the corresponding primary (virgin) materials, and the term secondary should not properly be used to describe inferior metal. The secondary materials are, of course, not ordinarily so pure as the corresponding primary metal and alloys made from primary metal. Secondary aluminum alloys are used largely in the production of aluminum-alloy castings. At the present time, there are several large firms in the United States engaged solely or very largely in the remelting of aluminum and alloy scrap and the recovery of the metal and its alloys from various wastes and residues.

Aluminum Producers of the World. The world output of primary aluminum is controlled by five groups of producers: the American, German, Swiss, French, and British interests. All of the aluminum-producing firms either own or control extensive deposits of bauxite, hydroelectric power plants, carbon-electrode factories, alumina-preparation plants, aluminum-reduction works, rolling mills, fabricating plants, and foundries. They make all kinds of manufactured and fabricated articles in aluminum and aluminum alloys. For many years, the United States has turned out about 50 per cent of the world's production of primary aluminum, and the dominant factor in the world is the Aluminum Co. of America. A number of countries, including Australia, Belgium, India, and Japan, are substantial consumers of aluminum but do not produce primary metal.

Distributing the 1925 output among the producing firms, the amounts of metal turned out by the different companies were about as shown in Table 2. Total reduction-cell capacity of the world is now about 325,000 metric tons per annum, and the relative capacities of the different producing countries as of 1926 is about as shown in the accompanying diagrammatic wheel of Figure 4. In the main, the physical capacity of producers has been taxed to the limit for several years, taking into account the shortage of hydro-

TABLE 2

Estimated World Output of Primary Aluminum in 1925, Distributed by Producing Companies

Company	Main Office	Reduction Works in	Output, Metric Tons
Aluminum Co. of America	Pittsburgh, Pa., U. S. A.	United States, Canada ([c]), and Norway ([d])	103,000
L'Aluminium Français	Paris, France	France and Norway	30,500
Société Anonyme pour l'Industrie de l'Aluminium	Neuhausen, Switzerland	Switzerland, Austria, France, and Germany	25,000
Aluminum Co. of Canada, Ltd.	Toronto, Canada	Canada	17,000
German Government-owned works ([a])	Berlin, Germany	Germany	24,000
British Aluminium Co., Ltd.	London, England	Scotland and Norway	11,000
L'Aluminio Italiano ([b])	Milan, Italy	Italy	1,830
Aluminium Corporation, Ltd.	Dolgarrog, Wales	Wales	1,000
Total			213,330

[a] The present producing plants in Germany are the Erftwerk, the Lautawerk, and the Innwerk, and one small plant of the Société Anonyme pour l'Industrie de l'Aluminium.

[b] Including Società per la Fabbricazione dell'Aluminium.

[c] Plant of subsidiary, the Aluminum Co. of Canada, Ltd.; output given under this company.

[d] Plant of subsidiary, the former Norsk Aluminum Co., in Norway; output in 1925 about 10,000 metric tons.

electric power. In the past three years, there have been several severe droughts in many parts of the northern hemisphere, and these have stringently limited the output of a number of hydroelectric power plants. At the present moment, productive capacity for pig as governed by hydroelectric facilities is below consumption demands, and while various producers are increasing physical aluminum plant for new output, there is need for more vigorous effort to bring hydroelectric power plant up to the existing level of reduction-cell capacity.

In the United States, the entire production of primary aluminum is made by the Aluminum Co. of America, and there is, in fact, no competing aluminum producer on the western hemisphere. More

complete details regarding the operations of this company are given in later paragraphs under the caption Development and Position of the Aluminum Co. of America. The present aluminum-reducing works of Austria are those at Lend and Rauris in the Austrian Tyrol, owned by the Société Anonyme pour l'Industrie de l'Aluminium of Neuhausen, Switzerland, often called the Aluminium Industrie Aktien Gesellschaft. The aluminum-pro-

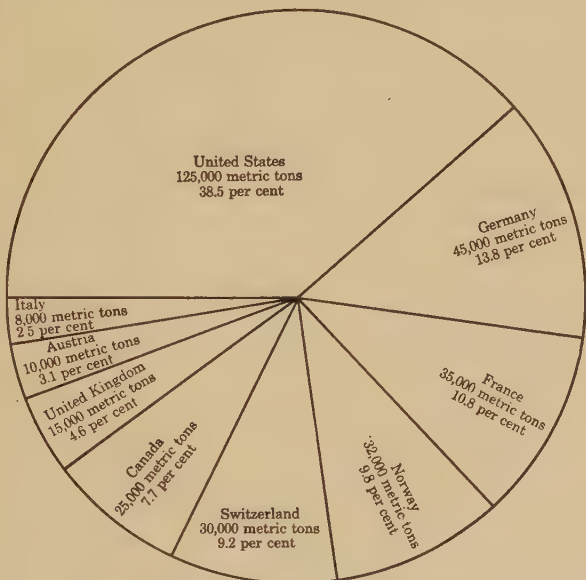

FIG. 4. —Aluminum reduction-cell capacity of the world, 1926.

ducing concern of Canada is the Aluminum Co. of Canada, Ltd., formerly known as the Northern Aluminium Co., Ltd., which for a number of years has operated a reduction works at Shawinigan Falls, Quebec. This is a subsidiary of the Aluminum Co. of America, and it will also operate the new plant at Arvida on the Saguenay River, now in course of construction. This new plant when completed will be the largest aluminum-reduction works in the world, with a total ultimate capacity of 400,000,000 lbs. of metal per annum. Control of all producing plants in France is held by L'Aluminium Français, a consolidation of five concerns. Conditions in France have changed markedly in the past few years, and France has become an importer of metal instead of an exporter.

Home consumption has increased until it is greater than the production, and plant enlargements are being made to satisfy the demand. Prior to the World War, the only aluminum-reduction works in Germany was the Rheinfelden plant, in Baden, of the Société Anonyme pour l'Industrie de l'Aluminium. This produced only about 1,500,000 lbs. per annum. Five plants were erected in Germany between 1914 and 1918, these being built under the stress of war necessity. The German war works were operated with electric power generated by lignite-fired steam plants and were distinctly uneconomical. A modern reduction plant, known as the Innwerk, served with hydroelectric power, was built in the Bavarian Alps after the War and started operations in 1925. This works is now the backbone of the German industry, although two of the war plants are still operating. Control of the German producing industry is held by the state. The German aluminum industry has passed through trying times in recent years owing to the poor industrial situation and the fact that the steam-power plants could not operate economically. At the present time, however, the outlook for the German industry is good.

In Italy, the aluminum-producing industry has so far been small, but considerable expansion is planned. Norway has become one of the leading producing countries for aluminum in the past few years, and expansion there has been very rapid. The output has increased from about 800,000 lbs. in 1907 at one plant to 48,000,000 lbs. in 1926 at five plants. The Norwegian works are controlled by the Aluminum Co. of America, L'Aluminium Français, and the British Aluminium Co., Ltd. In Switzerland, the aluminum industry is operated by the Société Anonyme pour l'Industrie de l'Aluminium, already mentioned.

Extension of Production Facilities. A survey of the past twenty-five years shows that aluminum consumption is increasing as fast as new production capacity can be developed. At the present time, numerous extensions to existing production works are being pushed by the leading producers, and new works are planned for construction in several countries where aluminum has hitherto not been made. The most important new plant now under construction is that of the Aluminum Co. of America at Chute-à-Caron, in the Saguenay district of Canada, above mentioned. Additional new works, or extensions to old works, are in course of construction in Norway, Italy, France, and Switzerland.

New works are planned for Japan, Russia, Hungary, Czecho-Slovakia, and Spain, countries in which aluminum has hitherto not been made. The total new capacity which may be brought in by 1930 may amount to approximately 600,000,000 lbs. of metal per annum, making the total world capacity at that time about 1,200,000,000 lbs. Whether some of the contemplated plants will actually be built and produce metal is a matter for the future to decide. The student of the aluminum industry may well be skeptical when plants for new aluminum works are announced with a flourish, because hundreds of similar schemes in the past have come to naught.

Since good water power is one of the main requirements for economical and successful aluminum production, it is natural that countries having abundant water power and no use for such power should turn to a consideration of aluminum. However, water power is not the only requirement for successful aluminum production. The essential requirements include a combination of powerful financing, high technical skill, and adequate supplies of good-grade bauxite, as well as cheap and reliable electric power. The situation is entirely different when old and established concerns expand, as is the case with the Aluminum Co. of America in Canada, the state-owned German works at Töging (the Innwerk) in Bavaria, the British Aluminium Co., Ltd., at Lochaber, and the like. In such cases, it is simply a matter of normal growth of plant and business.

In France, new works have been built at Saint-Auban and Riouperoux, and another is in the course of construction at Vicdessos. The Aluminum Co. of America is reported to have plans for the erection of a reduction plant in France. Noteworthy developments are going forward in Norway, particularly at the works of the Norsk Aluminum Co., a subsidiary of the Aluminum Co. of America. The Aluminium Corp., Ltd., of Wales, a small producer, is expanding into Norway, with the erection of a good-sized works. Enlargement of its Norwegian plant is also being made by the British Aluminium Co., Ltd. Norwegian capacity is expected to be increased from about 64,000,000 lbs. to 130,000,000 lbs. per annum before long. Several extensions have been made to the Chippis works of the Société Anonyme pour l'Industrie de l'Aluminium in Switzerland, and the power supply is more ample than previously. Italian production is to be developed further in

new plants to be situated near the Istrian bauxite deposits. In Spain, the Sociedad Alumino Español has been formed recently by bankers at Urquijo together with certain aluminum producers. Considerable furore has been raised in Russia in the past several years over the erection of aluminum-reduction plants to utilize the Russian bauxites. The proposed works are expected to be in operation by 1928, and output at first will be only about 1000 tons per annum. At the same time, several of the leading aluminum producers have been examining Russian bauxite deposits and looking into the general situation with the view to possible production of metal in that country. Work has been done to determine the amount of hydroelectric power that can be developed on the Marowyne River in Dutch Guiana, and apparently some 200,000 hp. can be secured at a particular site. It is proposed to erect a reduction works near by to utilize bauxite from the Guianas. The Aluminum Co. of America is the projector of the scheme.

Aluminum Markets, Production, Imports, and Exports. The market situation in aluminum cannot be dealt with here other than in the briefest way, but it is of interest to touch upon the principal features. Aluminum is sold in the form of pig, ingots, sheet, powder, foil, shot, many manufactured forms, and as alloy castings. Consumers of primary pig normally buy to cover their requirements for three to six months ahead. Purchases are made under contract which defines the kind of metal, price, quantity, terms, and delivery. Spot aluminum is normally available in small lots. There is no future market in aluminum such as exists in copper. There is naturally a general absence of any trading market in the United States for primary aluminum, because prices are determined by the Aluminum Co. of America, as would naturally be expected in view of the high import duty on the metal. Importers usually offer foreign pig at the same price as the domestic grades, or a shade under. The leading foreign aluminum producers are represented in the American market. In general, the consumption at home of the principal foreign producing countries is much less than the possible supply, but in the United States, under normal conditions, the domestic supply is by no means equal to the demand. The United States, therefore, imports large tonnages of primary aluminum yearly. Statistical writers on aluminum often state that the visible supply of aluminum is usually about equal to current needs and that this condition of the market is

due to control of production. On the other hand, it is a well known fact that severe shortages of aluminum have been experienced by numerous consumers in recent years. The efforts made by producers of late to increase reduction facilities and the fact that most plants in the world are continually producing appear to argue very cogently that consumption would be much larger if metal were available. A very considerable surplus of aluminium loaded down the market for several years after the War, but this has been entirely cleared away since 1921.

For the past several years, the entire aluminum market situation has reflected great strength throughout the international price structure. Considerable weakness has been shown, however, since the fall of 1926. Demand for metal has been well balanced in the principal lines, and the market has generally been in a position where quite marked change in the production or consumption will be necessary to affect prices greatly, unless arbitrary changes are made by producers, and unless, of course, a reduction in the domestic import duty is effected. In 1926, domestic outside market prices opened the year as follows: 29 cents per pound for 99+ per cent primary aluminum pig; 28 cents for 98–99 per cent primary aluminum pig; 27.5 cents for primary No. 12 alloy; and 27–27.5 cents for 98–99 per cent secondary aluminum pig. At the end of the year, the outside market prices were as follows: 27 cents per pound for 99+ per cent primary metal; 26.8–27 cents for 98–99 per cent metal; 25.5 cents for primary No. 12 alloy; and 25–26 cents for secondary 98–99 per cent aluminum. Aluminum sheet (18-gage and heavier) sold at 40 cents per pound base, and aluminum coils (24-gage and heavier) at 37 cents. The average price of primary 98–99 per cent aluminum in 1926 was 26.99 cents per pound as against 27.19 cents in 1925. The highest price reached by this grade in recent years was 32.9 cents in December 21, 1920. The lowest price in recent years was 19 cents on November 15, 1921. As a rule, foreign prices of aluminum in the home markets are somewhat lower than in the United States.

The aluminum industry of the world has grown by leaps and bounds since the metal became relatively cheap commercially — about 1895 — and this growth appears to have only started. In tonnage output, aluminum now stands forth among the nonferrous metals, following copper, lead, and zinc. It is confidently expected that aluminum production will surpass the lead and zinc

outputs before many years have passed. In the United States, the production of aluminum in 1883 was about 83 lbs.; by 1887, it was 18,000 lbs.; in 1900 it had risen to 7,150,000 lbs.; in 1910, it was about 48,000,000 lbs.; while in 1918 it was about 225,000,000 lbs. In 1926, total world output of primary metal was evidently about the same as in 1925 (470,000,000 lbs), and the individual producing countries may be ranked as follows in the order of their outputs: United States (200,000,000 lbs.), Germany (66,000,000), Norway (48,000,000), France (46,000,000), Switzerland (44,000,-000), Canada (40,000,000), United Kingdom (16,000,000), Austria (6,000,000), and Italy (4,000,000 lbs.). Total European production in 1926 was approximately 230,000,000 lbs. as against 240,-000,000 lbs. for the United States and Canada. The United States has led all individual producing countries for many years, but Germany is rapidly coming to the front. The greatest individual producing country in the future is expected to be Canada. The rise of Germany is one of the outstanding developments of the industry since prior to the World War that country made only about 1,500,000 lbs. of aluminum per year. Table 3 shows the estimated world's production of aluminum by individual countries over a period of years. No actually reliable production figures have yet been published.

As mentioned above, the United States imports large tonnages of primary aluminum yearly, these imports coming mainly from Switzerland, Germany, Norway, and the United Kingdom. Aluminum exports from the United States have not usually been large, but in recent years the Aluminum Co. of America has been carrying on a drive for the foreign markets. Aluminum and alloy manufactures do not bulk large in international trade, although considerable tonnages of aluminum sheet are sold. The total importation of aluminum (pig, scrap, and alloys, dutiable) into the United States in 1925 was 43,409,546 lbs., as against 29,394,155 lbs. in 1924. Imports in 1926 were about 70,000,000 lbs., a new record. Increasingly heavy shipments are coming in from foreign plants of the Aluminum Co. of America. The exportation of pig, scrap, and alloys from the United States in 1925 was 8,130,222 lbs., valued at $1,835,213, as against 3,356,786 lbs., valued at $703,996 in 1924; in 1918, 20,152,798 lbs. were exported. The exports of plates, sheet, bars, and like manufactures in 1925 were 4,511,812 lbs., valued at $1,530,602, as compared with

TABLE 3

ESTIMATED WORLD'S PRODUCTION OF ALUMINUM

(In metric tons)

YEAR	AUSTRIA	CANADA	FRANCE	GERMANY	GREAT BRITAIN	ITALY	NORWAY	SWITZERLAND	UNITED STATES	TOTAL
1913	5,000	5,916	[a]13,503	800	10,000	[a]874	2,500	10,000	29,500	78,094
1914	4,000	6,820	[a]9,967	800	8,000	[a]937	2,500	10,000	40,600	82,924
1915	2,500	8,490	[a]6,020	2,000	6,000	[a]904	3,500	12,500	45,000	86,910
1916	5,000	8,800	[a]9,604	8,000	4,000	[a]1,126	6,000	15,000	63,000	120,233
1917	5,000	11,800	[a]11,066	15,000	6,000	[a]1,740	8,000	15,000	90,700	164,306
1918	8,000	15,000	[a]12,023	25,000	14,000	[a]1,715	7,500	15,000	102,000	200,328
1919	5,000	15,000	[a]10,255	15,000	10,000	[a]1,673	4,000	15,000	90,000	165,929
1920	2,000	10,000	[a]12,304	10,000	8,000	[a]1,238	5,000	12,000	90,000	150,542
1921	2,000	6,000	[a]8,380	10,000	5,000	[a]744	4,000	10,000	28,750	74,874
1922	4,000	9,0000	[a]7,494	12,000	9,500	[a]810	6,000	12,000	52,000	112,804
1923	4,000	16,500	[a]14,343	15,900	9,000	[a]1,473	[a]13,319	12,000	95,000	181,535
1924	3,000	16,000	18,500	18,400	7,000	[a]2,058	[a]19,948	19,000	85,000	188,006
1925	4,000	17,000	20,500	25,000	9,000	[a]1,830	23,000	20,000	93,000	213,330
Estimated capacity	10,000	25,000	35,000	45,000	15,000	8,000	32,000	30,000	125,000	325,000

[a] Official figures.

2,986,726 lbs., valued at $928,319 in 1924. The total exports of all other manufactures of aluminum in 1925 were 6,453,192 lbs., valued at $2,691,256, as against 6,783,240 lbs., valued at $2,540,075 in 1924, while the total exports of aluminum (pig and manufactures) in 1925 were 19,105,226 lbs., valued at $6,057,071, as compared with 13,126,752 lbs., valued at $4,172,390 in 1924. The total amount of aluminum manufactures (including plates, sheet, bars, and hollow-ware) imported in 1925 was 345,600 lbs., valued at $172,653, as against 1,203,915 lbs., valued at $421,828 in 1924. The value of all other manufactures imported in 1925 was $183,489, as compared with $138,360 in 1924. Data are given yearly by the writer in *The Mineral Industry* [1] covering the international trade movements in aluminum.

Uses and Applications of Aluminum and Its Light Alloys. A detailed recounting of all the uses of aluminum and its alloys would require a volume of itself, and only the principal applications can be mentioned here. In a general way, aluminum finds useful application wherever low specific gravity, malleability, ductility, high thermal conductivity, high electrical conductivity, resistance to corrosion, or pleasing appearance are *desiderata*. Aluminum has been generally substituted for copper and the light alloys for brass and bronze in general engineering work, as well as for iron and steel in many instances where price is not prohibitive. About 50 per cent of the world's production of aluminum is used in the form of light alloys, principally castings, while 50 per cent is employed as substantially pure metal in the form of sheet, wire, bars, rods, tubes, foil, and other finished and semi-finished manufactures, as well as powder and granulated aluminum. In the United States, about 50 per cent of the domestic output of metal had been consumed for many years by the automotive industry, and while automotive consumption has been falling off due to price wars waged in the cheap-car field, in the past the status of aluminum production in this country has been reflected fairly faithfully by the output of motor cars. Figure 5, showing the relation between the domestic aluminum and automotive outputs over a period of years, may be noted in this connection. At the present time, some 40 per cent of the aluminum consumed in this country is taken by the automobile industry, 10 per cent for electrical conductors, 20 per cent by the general engineering trades, 5 per

[1] McGraw-Hill Book Co., New York.

cent by the steel industry, 10 per cent for cooking utensils, and 15 per cent for miscellaneous purposes (aircraft, chemical-plant

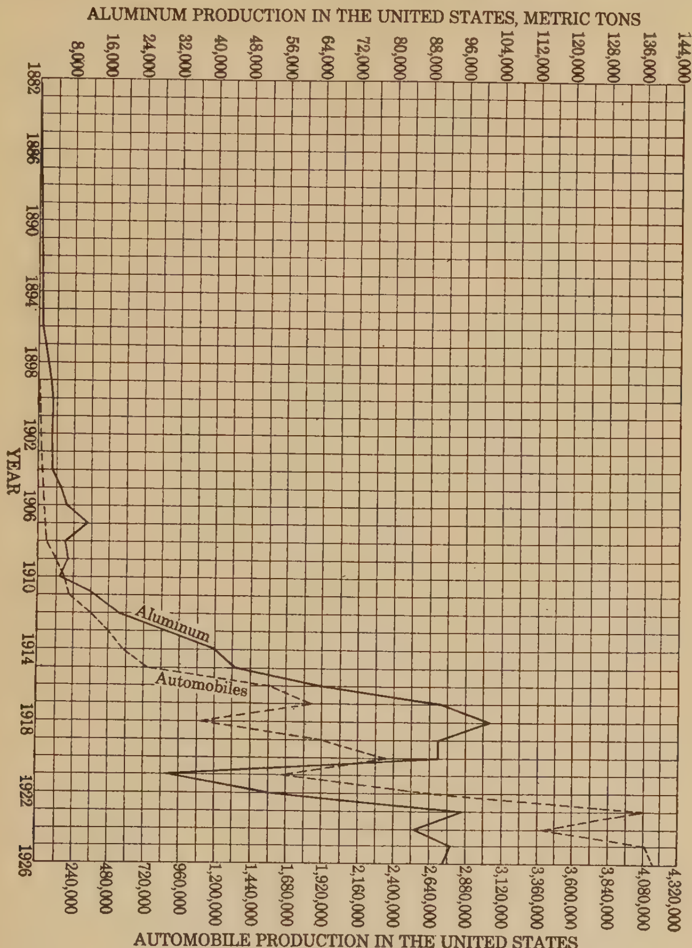

Fig. 5. — Relation between aluminum and automobile production in the United States.

equipment, paint, foil, etc.). An increasing amount of metal is being used in the form of alloys.

Substantially pure (commercial) aluminum is too soft and weak for many purposes, and its mechanical properties are improved, in some cases most remarkably, by the addition of suitable alloying

elements in definite proportions. Moreover, heat treatment notably enhances the strength of certain alloys. Commercially pure aluminum has definite fields of application where its special properties are desired. It is not to be expected that aluminum will ever be a complete substitute for copper. Each metal has definite specific qualities which indicate its use in preference to the other for particular purposes, irrespective of the price. Of course, where either can be used with the same utility, price is the determining factor. Owing to the considerable difference in density of copper and aluminum, the price per pound does not determine which is the cheaper to use — the price per unit of mass is the determinative. In recent years, the inability of Germany and France to finance copper import purchases (principally from the United States) has made for large substitution of aluminum, and in these countries aluminum has been used for some purposes where copper would be preferable.

The following industries are large users of aluminum or aluminum alloys, or both: aircraft, automotive, cameras and photography, chemical, confectionery, cooking utensil, electrical-appliance manufacturing, food, household appliance — including the vacuum-cleaner and washing-machine industries, — metallurgical reduction (aluminothermic), paint, power and public utility, printing, radio, railroad and street-railway equipment, rubber, steel, telephone equipment, typewriter as well as other business machines, toy, X-ray equipment, and the general casting industry. The general engineering trades are consuming increasing quantities of aluminum and its alloys. New uses of aluminum are being discovered from time to time, and the consumption for various known purposes is steadily increasing. The relationship of the domestic aluminum industry to other major industries is indicated by the principal uses of the metal and its alloys, while the importance of the aluminum industry to the country is clearly shown by the number, size, and scope of the principal aluminum consumers. There is scarcely a person or industry in the United States that is not touched in some way by aluminum. In 1918, the Allied Governments put about 200,000,000 lbs. of aluminum or alloys into aircraft alone. Aluminum is the preferred construction material for modern aircraft, and if the next war is fought in the air, as predicted by military experts, aluminum will be the determining factor.

The principal use of wrought or fabricated aluminum is in the form of sheet and wire. Aluminum sheet is employed for paneling and body work for motor cars and aircraft; for the manufacture of spun and drawn cooking utensils; for vats, tanks, autoclaves, and special apparatus in the diversified chemical industry, as well as for various appliances in the preparation of dyes, foods, and pharmaceutical products; and a considerable tonnage is used in the small stamping trade. One of the first outlets for aluminum was the cooking utensil. Aluminum foil is used extensively for wrapping tobacco, confectionery, and foods, and embossed, printed, and colored foil is produced. Aluminum foil has made rapid strides recently in competition with tin foil. Aluminum and aluminum-alloy rivets and screw-machine products are becoming very popular. Collapsible aluminum tubes are being used in large quantities as containers for non-alkaline toilet articles. Aluminum powder is the basis of the aluminothermic (thermit) process for the reduction of refractory oxides and the preparation of metals and ferro-alloys, as well as for the aluminothermic welding process in the repair of iron and steel parts. In steel metallurgy, aluminum shot and ingot are used at most works for deoxidation in ingot production. Aluminum powder is employed in the calorizing process and in the manufacture of explosives. The use of calorized steel pipe in oil-still work has gained ground recently. Remarkable developments are being made in the use of aluminum paint, particularly for general outside work in protecting iron and steel against corrosion and in painting oil-storage tanks and other containers for maintaining temperature low when exposed to the sun, thereby minimizing volatilization losses. There is large use of aluminum paint now around oil refineries and by-product coke plants, both for corrosion and heat-resisting purposes, and it is being employed as a general protective paint for both outside and inside (factory) purposes. The abrupt and widespread increase in the use of aluminum paint in the last few years has been most exceptional.

Aluminum cable is a serious competitor for copper and in the electrical industry, and aluminum is now used extensively for high-voltage transmission lines. Over 200,000 miles of aluminum or aluminum steel-cored cables are now in service, and this large mileage is being rapidly increased with many new and important installations. The great expansion in new hydroelectric power

projects all over the world has been reflected in a strong demand for wire and cable. Weight for weight, aluminum has twice the electrical conductivity of copper, and the lighter weight permits good economies in the construction of supporting towers of power lines. Figure 6 shows the power house with towers in the foreground, looking over the valley, of the new Hetch Hetchy hydroelectric installation of the city of San Francisco. Steel-reinforced aluminum conductors are used extensively in this project.

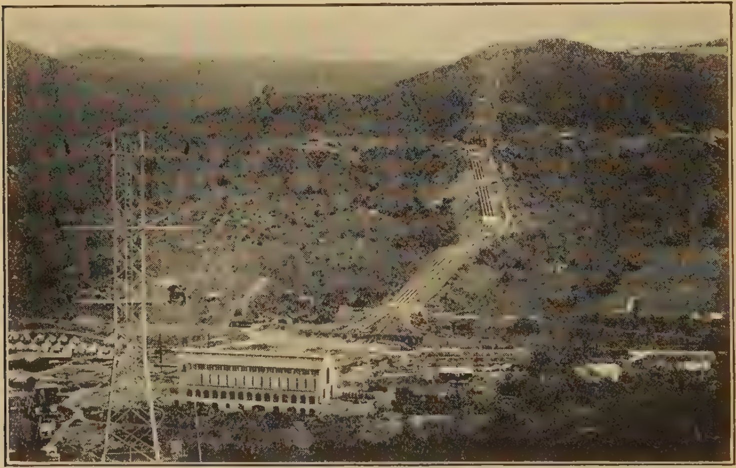

Fig. 6.—Moccasin power house of the Hetch Hetchy hydroelectric installation for San Francisco.

The present largest use for aluminum alloys is for the production of sand castings for automotive work, while die-cast and permanent-mold-cast parts are being employed in considerable quantities. Rolled alloys are used in a minor way, while forgings have just recently been developed. The light aluminum alloys, either cast or wrought, have applications in all branches of engineering construction, including motor-car manufacture, aircraft, railway, and marine work, internal-combustion engines, and for machinery in general. Other important applications are for the manufacture of cast cooking utensils, vacuum cleaners, washing machines, radio, in the electrical-manufacturing industry, baking machinery, certain machine tools, for patterns and flasks in founding, ornamental wares, and for scientific and testing instruments.

Aluminum alloys, as substitutes for cast iron, steel, brass, or

bronze, may be given consideration by the engineer for several reasons which make a direct appeal: (1) light weight, *i.e.*, low specific gravity; (2) high specific tenacity — on a strength-weight basis, light alloys in the cast condition are available which are equivalent to steel having tensile strength of 180,000 lbs. per square inch; and (3) on a price-mass basis, a light aluminum alloy may be cheaper than a ferrous- or cuprous-alloy part, despite the relatively high cost of aluminum on a pound basis. The specific gravity of the useful aluminum alloys is low, ranging from about 2.6 to 3, as against 8.4 to 8.9 for brasses and bronzes, and 7.2 to 7.9 for cast iron and steels. The specific tenacity of an ordinary aluminum alloy (having tensile strength of about 20,000 lbs.) is more than double that of cast iron (tensile strength 21,000 lbs.), and is about equal to that of monel metal (tensile strength 70,000 lbs.) and of cast steel (tensile strength 60,000 lbs.). On a price-mass basis, it is often economical to substitute cast aluminum-alloy parts for other materials. Thus, considering bronze: if a given bronze casting weighs 4 lbs., the raw-material cost will be about 52 cents (at 13 cents per pound). The same casting in an ordinary aluminum alloy would weigh only about 1.3 lbs., and the raw-material cost would be 32 cents (at 24 cents per pound). Of course, it is not a question of the raw-material cost alone which should determine the specification of materials, but account should be taken of the cost of fabricating. Aluminum can be fabricated at less cost than copper, brass, or steel, and the aluminum alloys can be machined at much greater speeds than the cuprous and ferrous alloys. The fabrication and machining items naturally have important bearing on the total cost of a finished part.

Striking advances have been made in the past five years in the development and use of heat-treated aluminum-alloy parts for structural purposes. The tensile strength of the usual aluminum alloys as cast varies between 18,000 and 30,000 lbs. per square inch. Heat-treated cast alloys have been produced with strength of 50,000 lbs.; wrought and heat-treated duralumin can be produced in regular practice with strength exceeding 60,000 lbs.; while the strength of heat-treated duralumin can be raised to 80,000 lbs. by cold working. With the development of special alloys and heat treatment, aluminum alloys can be, and are now being, used for many more purposes than was previously possible. It is expected that in the future the majority of aluminum-alloy castings will be

of the type now regarded as special, *i.e.*, of special composition and heat treated. There is a great future for heat-treated castings in motor-car construction, and already crankcases, pistons, bearing caps, brake shoes, and some other parts are being heat treated. Eventually, the use of the light alloys for a wide variety of moving parts under quite high stresses may become standard practice.

Until recently, the value of the aluminum alloys had been felt most strongly by the automotive and aëronautical engineer; they have been recognized as advantageous mainly for applications in which the saving of weight and the attainment of the highest degree of efficiency were of paramount importance. The saving of weight in all forms of transportation is reflected normally in the saving of fuel; hence railroads and shipbuilders are becoming interested in the light alloys. The possible extent to which aluminum and its light alloys can be used in railway work is being studied, and the prospects for considerable consumption of these materials for railroad and street-railway equipment are bright. Several prominent railroad lines in the United States have ordered cars built with considerable quantities of aluminum and duralumin used in their construction. A number of street cars have been built in the same way. Great reduction of dead weight in large structures and machinery can be effected by the substitution of aluminum alloys for cuprous and ferrous materials, and lighter rolling stock means decreased power required for haulage. The saving of weight in parts which are put in motion and stopped alternately or periodically, as in reciprocating parts of moving vehicles, is highly important from the point of view of fuel or power economy, as well as wear and tear. Hence, another large potential field for the light alloys is in moving parts of industrial machinery, such as textile machinery, looms, knitting and weaving machines, and in machine tools.

The metal construction of aircraft is becoming more general and is favored by aëronautical authorities, and the outlook for greatly increased use of high-strength aluminum alloys is bright with the growing importance of commercial aviation. Recent trials of large dirigibles like the *Los Angeles* have shown that duralumin is entirely trustworthy as a structural material for this class ship; in fact, this is about the only suitable material now available. Figure 7 shows a view of the dirigible *Los Angeles* of the U. S. Navy, which is typical of the modern dirigible ship. Experience with air-

craft engines has had its effect on motors for automobiles, and there will be more plentiful use of aluminum alloys in motor-car engines in the future. Figure 8 shows the 450 horsepower Maybach aircraft and marine engine, in which aluminum alloys are used extensively. The forged duralumin connecting rod is being used on eight makes of American motor cars, and there appears to be promise of considerable expansion in this development. The aluminum-alloy piston for both motor-car and aviation engines has been demon-

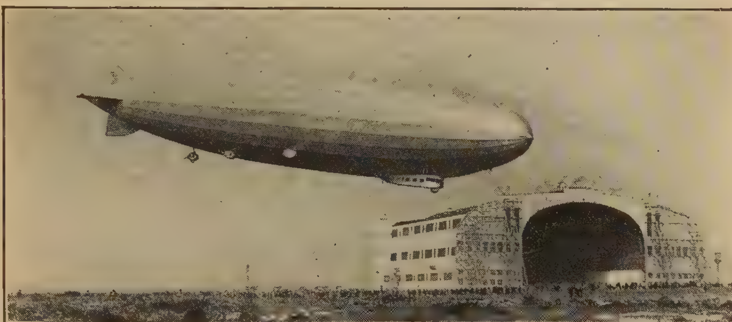

FIG. 7. — Dirigible *Los Angeles* of the U. S. Navy, entering hangar (U. S. Navy).

strated beyond any doubt as superior to cast iron, and the light alloy piston has been adopted recently by a number of American motor-car builders who formerly used cast iron exclusively. Eventually, the aluminum-alloy piston will be standard equipment for all American motor cars, including those in the lowest price classes. There has also been widespread adoption of the aluminum-alloy piston for diesel and marine engines in the past few years. The aluminum-alloy wheel as a substitute for steel or wooden-spoke wheels is being used considerably abroad, particularly for busses, and extended tests have shown that these wheels are entirely reliable.

A broad field for aluminum and its light alloys is in the construction of motor busses. Bus transportation is growing with great rapidity for American urban and interurban travel, and the trend is toward light construction. Lighter busses mean less wear on tires and road surfaces, lower gasoline and oil consumption, easier operation, and greater capacity for a given weight. Figure 9 shows a modern type of bus for city transportation in which a substantial amount of aluminum alloys is used. The use of

aluminum, and more especially alloys, on board ship is in its infancy but growing. There is a great potential field here, both in

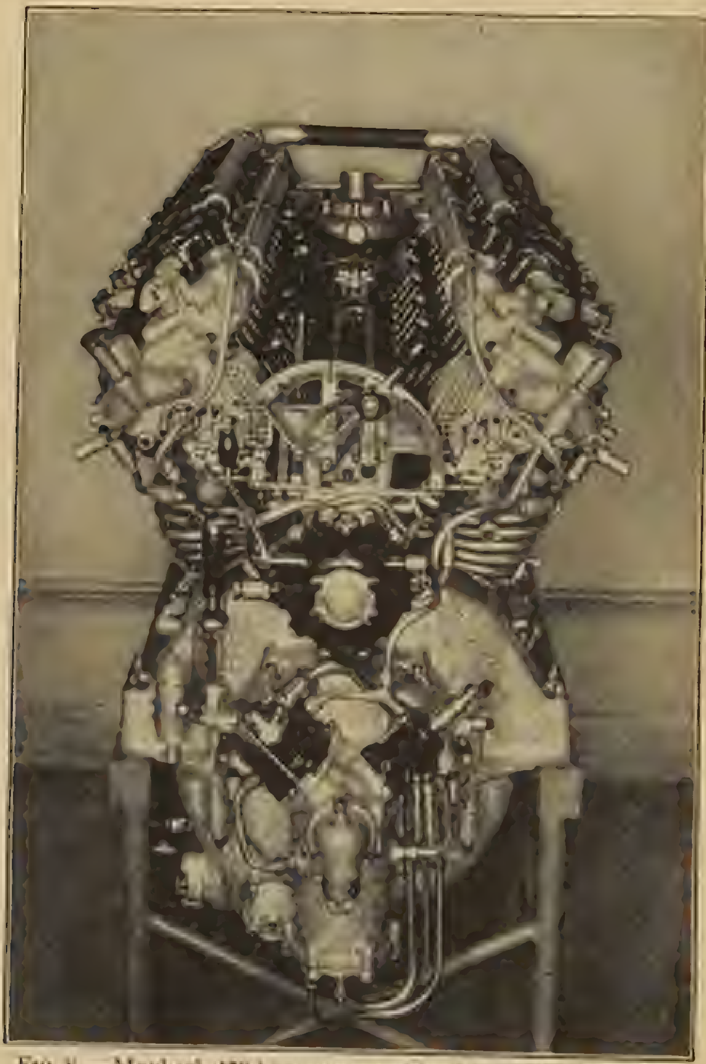

Fig. 8.—Maybach 450 horsepower engine (Maybach Motor Co.).

connection with warships and vessels in the mercantile marine. The Washington Conference which set a limit on the tonnage of new warships naturally encouraged naval engineers to look into

the merits of aluminum alloys. The main argument for the use of aluminum on board ship is its low specific gravity, and for a given tonnage, more power, more ships, more guns, greater cruising radius, or other advantage can be obtained by the substitution of aluminum alloys for heavier materials where feasible. Hence, aluminum and its light alloys are being adopted for a number of applications in marine work on the principle that a small saving in weight in many small parts will amount, in the aggregate, to a very material increase in capacity for additional armament or engine horsepower.

FIG. 9.—Modern type of bus for city transportation. (International Motor Co., Mack Trucks, Inc.).

Metallurgical Progress. Many new and interesting developments are being made in the technical metallurgy of aluminum, but only a few of the more important can be touched upon here. Research carried out in the last few years has yielded results of great commercial value in various branches of the industry from the mining of bauxite to the fabrication and utilization of the metal and its alloys.

The development of the Hoopes process for the reduction of pure aluminum and the refining of impure grades is one of the outstanding achievements of the research engineer. It is only recently that *pure* aluminum has been produced. The ordinary good commercial grades of metal are relatively impure, as compared to commercial copper, zinc, and tin for example. Many attempts had been made to refine impure aluminum and produce pure metal without success prior to the development of the Hoopes process a few years ago. Patents covering this process are held by the Aluminum Co. of America. Briefly stated, the essence of the

Hoopes process is the electrolytic refining of impure aluminum, the steps comprising establishing between a lower layer of liquid alloy containing aluminum, as anode, and an upper layer of liquid aluminum, as cathode, an intermediate layer of fused electrolyte of greater density than the liquid aluminum and composed essentially of fluorides (and substantially free from chlorides), and passing current from the anode through the electrolyte to the aluminum cathode, whereby aluminum is removed from the anode alloy and deposited in the liquid state on the cathode. The resultant metal has been made to contain 99.98 per cent aluminum. This process promises to be of great commercial and technical importance. The properties of pure aluminum are markedly different from those of commercial 99 + per cent metal.

Several new and important processes have been developed lately for the production of alumina from bauxite, as well as from low-grade aluminous minerals, and there is a possibility of the metal and certain of its alloys being made by the direct smelting of ore in the electric furnace. The most important of the new alumina-preparation methods include the Haglund, Blanc, Pedersen, and Lederer processes. Aluminum may before long be made commercially from aluminous minerals other than bauxite, including leucite, kaolins, and potash feldspars. In the Haglund process, alumina is made by the direct carbon smelting of bauxite or other aluminous minerals in the electric furnace, using an aluminum-sulphide slag; ferro-silicon is a by-product. This process is one of the most notable developed in recent years. The first large-scale installation of the Haglund process is to be made in Germany. In the Lederer process, aluminous minerals, such as clay, are heated under pressure in an autoclave, and then the reaction mixture is refrigerated. The alumina obtained is said to be very pure. The Blanc process is used for the preparation of alumina, potash, and silica from leucite by the hydrochloric-acid treatment. In the Pedersen process, a highly aluminous slag is made in the blast furnace from the smelting of iron ores by charging bauxite or other aluminous ore instead of limestone. The slag is treated with sodium-carbonate solution to yield alumina. In Japan, the sulphurous-acid process has been developed for the preparation of alumina from alunite and other aluminous minerals. In passing, it is of interest to point out that certain of the bauxite deposits of the Gold Coast (Africa) carry gold and silver in appre-

ciable amounts, and the values might be recovered from the insoluble residues resulting from treatment by the Bayer process, thus enhancing the value of the ores.

A wealth of important data has been made available in the past ten years on the mechanical and physical properties of aluminum and various aluminum alloys, and adequate information is now available to the engineer as a guide to the properties of these materials. Several new aluminum alloys are available today which possess striking properties as compared with those used only a few years ago. The strength, ductility, corrosion resistance, and alternating-fatigue behavior of certain new alloys are very satisfactory. There is a well-defined trend toward multiplication of the number of alloys being used, and the past ten years have witnessed an almost complete revolution in the development and use of the light aluminum alloys. The progress of heat treatment as applied to aluminum alloys has already been mentioned, and here it should be added that the more theoretical aspects of the phenomena involved in the heat-treatment processes have been subjected to detailed scientific study in recent years. Simultaneously, the metallography of aluminum and its light alloys has been studied until this branch ranks with the metallography of steel as a developed science It is of interest to point out that prior to 1920, silicon was generally regarded as a harmful, or at least undesirable, element in aluminum. Due to studies by Pacz and others, most interesting and useful aluminum-silicon alloys have been developed. Pacz introduced the "modification" process, so-called, into aluminum metallurgy, this being a novel instance of colloid metallurgy which has now spread to other fields. By the treatment of certain aluminum-silicon alloys with an alkaline-fluoride flux or with other reagents, the strength of such alloys may be increased 50 per cent and the ductility tripled.

Sundry processes for producing colored coatings on aluminum and its light alloys have been brought out recently, and certain of these appear to have commercial possibilities. The employment of methods for protecting these materials against corrosion in service is gaining ground, the anodic-coating process in particular giving good results and being used considerably. Anodic coatings are resistant to corrosion by sea water. In aluminum-alloy die casting, there has been marked increase in size and complexity of castings made, and notable developments in die-casting machines.

The die-casting process has made great strides in the United States, but has moved slowly abroad. There has been considerable activity lately in the development of processes for electroplating aluminum and its alloys, and cadmium-plating gives especially good results. A better knowledge of casting conditions for aluminum alloys has resulted in the regular production of parts that are much stronger and more uniform in quality than those formerly made. Permanent-mold casting is making inroads on the sand-foundry business, and before long a permanent-mold department will be a necessary adjunct to both sand foundries and die-casting plants. X-ray examination is being applied to aluminum-alloy castings for the location of internal defects. X-ray examination promises to be one of the most important testing methods in castings production, and it is well adapted to aluminum-alloy examinations because of the relative transparency of the metal. The aluminum-alloy piston has made large gains in the automotive field, as previously indicated; important technical advances have been made in the past few years in piston design, and much improved piston alloys have been introduced. Metallurgical practice in the production of secondary aluminum and alloys has shown some improvement, and increasing difficulties are being experienced in recovery due to the changing character of the scrap that is coming back. Larger furnaces are being employed in secondary work, and fluxing methods are being improved. Welding, as a fabrication process in manufacturing aluminum apparatus, has been developed to an efficient state. In the case of wire, aluminum-alloy conductors have been introduced recently having about 95 per cent of the electrical conductivity of aluminum and much greater strength. This type of conductor may be a strong competitor of the steel-reinforced aluminum cable.

Many problems remain to be solved in the melting, casting, working, and finishing of aluminum and its light alloys, but systematic investigation is being applied throughout the field with very gratifying results.

Development and Position of the Aluminum Co. of America. The history of the domestic aluminum industry is very closely tied up with the history of the Aluminum Co. of America. Monopolization of the bauxite deposits of the United States by this company and its monopoly of the domestic production of aluminum, which is fortified by high import duties, make it impossible to consider

conditions in the aluminum industry separately from the position of the Aluminum Co. of America. The present Aluminum Co. of America is the outgrowth of Charles M. Hall's early experiments at Oberlin College to make aluminum. In 1888, a corporation was formed in Pittsburgh for the exploitation of Hall's knowledge and experiments. This was known as the Pittsburgh Reduction Co., and A. W. Mellon supplied the necessary financial assistance to Hall originally. The first officers of this company were A. E. Hunt, president, C. M. Hall, vice president, and A. V. Davis, secretary and general manager (the latter being the present president of the Aluminum Co. of America). After the formation of the Pittsburgh Reduction Co., a plant was put into operation at New Kensington, Pa., and the effort was made to sell aluminum in the open market. Progress was very slow at the outset. In 1890, aluminum was little known, costs of production were high, and many difficulties were experienced in handling the metal. For many years, almost every use of aluminum was a new use, and the company was compelled to manufacture and fabricate various products in order to prove that the metal or its alloys could be employed satisfactorily for given purposes. The early years of the company were spent largely in solving many technical and engineering problems connected with the development of the Hall process, in reducing production costs, and in finding outlets for the metal. The requirement of cheap power was early recognized, and when hydroelectric power became available at Niagara Falls, the company acquired a site there.

In 1899, A. E. Hunt died, and R. B. Mellon, brother of A. W. Mellon, was made president of the company. From 1900 on, the business of the company increased rapidly, and new reduction plants were located at strategic points. It was necessary also to install power plants for the company's own use. The plant at Massena Springs, N. Y., was completed in 1903. In 1906, the company began to acquire the property necessary for the development of some 800,000 horsepower on the Long Sault in the St. Lawrence River, but so far it has been impossible to coördinate the necessary legislation to dam the river. In July, 1905, the Pittsburgh Reduction Co. acquired from the General Chemical Co. all the capital stock of the General Bauxite Co., thus obtaining control of the bauxite properties of this company. On January 1, 1907, the name of the Pittsburgh Reduction Co. was changed to

the Aluminum Co. of America. In April, 1909, this company purchased from the Norton Co. the Republic Mining and Mfg. Co. with all its bauxite properties. As a result of these transactions, the Aluminum Co. of America acquired a monopoly of the commercial bauxite deposits available in the United States and suitable for aluminum reduction. Incident to these purchases, agreements were entered into providing for the sale of bauxite to the General Chemical Co. and the Norton Co., but binding these companies not to use or sell any of the bauxite purchased to others for use in the production of aluminum. These bauxite transactions and certain other agreements alleged to be in restraint of trade, notably a contract between the Aluminum Co. of America (through its subsidiary the Northern Aluminum Co., Ltd.) and the Société Anonyme pour l'Industrie de l'Aluminium, of Neuhausen, Switzerland, in which the latter agreed not to sell aluminum in the American market, were brought to the attention of the Department of Justice. In 1912, judicial proceedings were brought against the Aluminum Co. of America, under the Sherman anti-trust act. As a result of the proceedings, the company consented to a decree requiring it, among other things, to cancel portions of the contracts and agreements complained of and to refrain from indulging in the unfair methods of competition enumerated in the complaints. This ruling is the famous "consent decree of 1912" and has subsequently been made the basis for many attacks against the Aluminum Co. of America.[1]

Prior to the World War, the Aluminum Co. of America turned its attention to water power in the Great Smoky Mountains on the Little Tennessee River and its tributaries, where water powers of large capacity were acquired and have been partly developed. However, increased costs both during and since the War have rendered further development of these powers too expensive for aluminum reduction. In 1915, the Aluminum Co. of America acquired the plant of the Southern Aluminum Co. at Whitney, N. C., which had been started and partly completed by L'Aluminium Français. Operations of the French company in construction of this plant were stopped in 1915 due to the War, and purchase of the entire property was made by the Aluminum Co. of America. In 1921, the company turned its attention to

[1] Cf. Federal Trade Commission's and Other Governmental Investigations of the Domestic Aluminum Industry, below.

Norway with the object in view of securing abundant and cheap water power for enlarging its operations. Since then, it has acquired lands for the development of several good powers and has also obtained control of the Norsk Aluminum Co. and Det Norske Nitrid, two companies previously engaged in aluminum reduction in Norway. In 1924, the Aluminum Co. of America acquired an important group of fluorspar mines in Illinois and Kentucky, adding to its previous holdings in order to have ample supplies for making artificial cryolite. This transaction made the company the dominant factor in the fluorspar mining industry of the United States. The latest development of the Aluminum Co. of America is that on the Saguenay River in Canada. In the main, the present ramified organization of the company has been developed by the expansion of its own plants and business, and not by the consolidation of independent aluminum concerns. In recent years, however, it has tended to enlarge by the acquisition of other companies.

Canadian Development. The most important industrial development in the history of the aluminum industry is the new reduction works and power project of the Aluminum Co. of Canada, Ltd. This plant is expected to be eventually the largest aluminum-reduction works in the world. A new city, called Arvida, is being built at the site of the works. Exploration, pioneer agricultural development, lumbering, and paper pulp manufacture, which have in turn progressed in the Saguenay Valley, are now being supplemented by aluminum reduction. The reduction works is now in course of erection at Chute-à-Caron, and metal was first produced here in the fall of 1926. Power is supplied temporarily from the Duke-Price hydroelectric plant at Île Maligne, where 360,000 horsepower is now being made, and 540,000 horsepower will be developed eventually. A larger power plant is to be constructed by the Aluminum Co. of America at Chute-à-Caron; this is to develop 800,000 horsepower and be ready for the production of aluminum by the end of 1928. The total available power in the district is sufficient to produce 250,000 metric tons of aluminum per annum. The total expenditures to be made in developing the power plants, reduction works, alumina plant, and electrode factory are expected to total $100,000,000. Ocean-going steamers can ascend the Saguenay River as far as Chicoutimi, and bauxite is to be shipped on an all-water route direct from the Guianas. This project is a result of a merger of the Duke interests (the Cana-

dian Mfg. and Development Co.) with the Aluminum Co. of America. New financing has been provided by the Aluminum Co. of America to take care of the work.

The chief factors which have contributed to this project are availability and cheapness of hydroelectric power, good labor supply, and water transport. Power costs in the district are evidently the lowest in the world. While the great power on the Saguenay River had been known for many years and partly utilized, it was not adaptable for aluminum reduction until large deposits of bauxite situated on tidewater were developed. Bauxite is not known to occur in tonnage quantities and of suitable grade for aluminum production in Canada. The necessary condition for the utilization of the Saguenay power for aluminum reduction was created by the development of the Guiana bauxite deposits. Whether the aluminum produced at the Saguenay plant will be exported to countries other than the United States, in a drive for the foreign markets, or whether the United States requirements alone will be supplied, is not known. If this new Canadian output is imported into the United States, there is a reasonable possibility of reduction in the domestic import duty on aluminum pig. As a result of the merger with the Canadian Mfg. and Development Co. above referred to, the present Aluminum Co. of America is technically a new concern.

This great development of the Aluminum Co. of America is an excellent illustration that the world is becoming industrially very small. Cryolite will come from Greenland and bauxite from South America thousands of miles by water to a Canadian water-power site so that aluminum can be produced cheaply. The metal will then be shipped by water to consumers all over the world for fabrication into useful products of everyday life. Figure 10 is a flowsheet, indicating the operations at Arvida.

Capital Structure. The capital stock of the Pittsburgh Reduction Co. at the date of its incorporation in 1888 was $20,000, which was paid for in cash. During the latter part of 1889, the authorized capital stock was increased to $1,000,000, a portion of this being issued for the Hall patents. Throughout the next several years, the remainder of the authorized stock was issued from time to time, either for cash or, in certain instances, for patents and other expenses, so that by 1897 the entire $1,000,000 of stock was issued and outstanding. In 1898, the authorized capital stock was in-

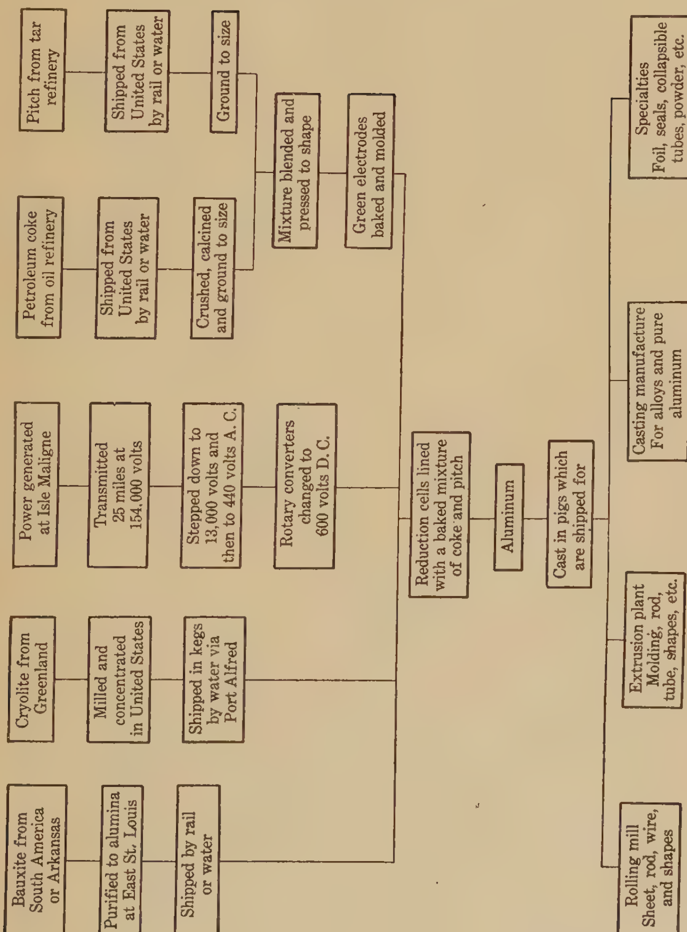

FIG. 10.—Flowsheet of aluminum works of the Aluminum Co. of Canada, Ltd., at Arvida, Province of Quebec.

creased from $1,000,000 to $1,600,000, by the issuance and sale of $600,000 of preferred stock. In 1904, the authorized capital stock was increased from $1,600,000 to $3,800,000 by the authorization of 22,000 ($2,200,000) of common stock. This increment of 22,000 shares was disposed of as follows: 10,000 shares as a 100 per cent dividend to the common stockholders of record; 10,000 shares were offered for sale to the stockholders at par, and 2,000 shares were retained in the treasury.

In 1909, the authorized capital stock was reduced by $600,000 to $3,200,000 by the retirement of the $600,000 of outstanding preferred stock. Coincidentally, with the retirement of this stock the authorized common stock was increased from $3,200,000 to $20,000,000. This increase (168,000 shares of $100 par value) was disposed of in the form of a 500 per cent stock dividend to the common stockholders of record. Following this stock dividend, there were issued and outstanding $18,729,600 par value of the stock of the company, the remainder of the $20,000,000 authorized stock being either in the treasury or unissued. Until July of 1925, the capital stock of the company, then, consisted of 200,000 shares with a par value of $100 per share, of which about 187,000 shares were issued. There was no definite market value for this stock, since it was not listed on any exchange and little of it ever changed hands. The value was regarded as about $800 per share.

The new Aluminum Co. of America was created by merger with the Canadian Mfg. and Development Co. on July 29, 1925. The authorized capital stock as of date of the merger consisted of 1,500,000 shares of 6 per cent cumulative preferred stock of a par value of $100 per share, and 1,500,000 shares of common stock without nominal or par value. In exchange for 1 share of the old $100 par stock of the former Aluminum Co. of America and for 20 shares of stock of the Canadian Mfg. and Development Co., 7 shares of the common stock of the new Aluminum Co. of America were issued. One half of the preferred stock so issued accumulates dividends from July 1, 1925, and the other half from January 1, 1927. This latter half of the preferred stock was represented by warrants exchangeable on January 2, 1927, for definitive preferred stock similar in all respects to the preferred stock accumulating dividends from July 1, 1925. There are presently outstanding some 1,470,000 shares of the common stock having a market value of about $7,400,000. Of the present stock, 80 per cent is held by

the directors of the company, 11 per cent by the Duke tobacco interests, and the remainder by employees and others. The actual ownership and control of the company is held by A. W. Mellon, Secretary of the Treasury of the United States, and his brother, R. B. Mellon, Chairman of the Mellon National Bank of Pittsburgh, Pa.

Early in 1927, $60,000,000 of 5 per cent sinking fund gold debenture bonds of the Aluminum Co. of America were offered to the public by a syndicate of leading investment bankers. The proceeds of these bonds were to be used to retire the company's entire funded debt (previous small borrowings having been made), to pay a small bank indebtedness incurred in connection with its Canadian building program, and for other corporate purposes, mainly the building of a new hydroelectric-power plant at Badin, N. C., and for the development of the plant at Arvida. For the 10 years ending December 31, 1926, the net income of the company, after taxes and depreciation, available for interest has averaged over $12,000,000 per annum and for the last three years such net income has been respectively as follows: 1924, $13,425,266.69; 1925, $22,891,505.40; and 1926, $19,747,068.85. The company will pay annually to the trustees a sinking fund as follows: On the first day of January of each year from 1929 to 1937, $1,000,000, and on the first day of January of each year from 1938 to 1951, $2,000,000. The present quoted prices of the preferred stock and the common capital stock of the Aluminum Co. of America indicate a value exceeding $250,000,000. Since its inception, the policy of the company has been to put back a large portion of its earnings into the business. For the last five years, the amount put back has averaged more than 75 per cent of the earnings before dividends. The present directors of the Aluminum Co. of America are A. V. Davis, R. B. Mellon, R. A. Hunt, G. G. Allen, A. K. Lawrie, G. H. Clapp, E. K. Davis, R. E. Withers, and G. R. Gibbons. A. W. Mellon retired as a director of the company when he became Secretary of the Treasury.

Subsidiaries. The primary business of the Aluminum Co. of America is the reduction of aluminum from its ores, at smelting works situated at various points in the United States and in foreign countries. The hydroelectric plants for the development of the electric power required are either owned by the company or power is obtained under long-time leases at such rates as make these

leases very valuable. In addition, the company has several undeveloped water powers and powers in the course of development which, when utilized, will considerably more than double the present supply of power. In addition to its bauxite-mining properties in the United States, the company owns three concerns holding bauxite-mining properties in Europe. Five subsidiary companies are engaged in mining bauxite on a large scale, two in the United States, two in South America, and one in Europe. The plant for the preparation of alumina is operated by a subsidiary, the Aluminum Ore Co., at East St. Louis, Ill. The parent company and four subsidiaries operate eight reduction plants, situated at Niagara Falls and Massena, N. Y., Alcoa, Tenn., Badin, N. C., Shawinigan Falls and Arvida, Quebec, and in Norway. The Aluminum Co. of America owns or controls some dozen companies producing aluminum and aluminum-alloy manufactures, including sheet, rod, wire, foil, tubes, special shapes, cooking utensils, paint, and castings. Its manufacturing and fabricating plants are situated at Alcoa, Tenn., New Kensington, Pa., Edgewater and Garwood, N. J., Buffalo, Niagara Falls, and Massena, N. Y., Cleveland, Detroit, Fairfield, Conn., Toronto, Canada, and in England, France, and Germany. The parent company owns five railroads and six sales organizations, these latter handling the sales of aluminum and manufactures thereof, largely abroad. The parent company owns a number of power and public utility companies, the main object of which is the production and transmission of power for its aluminum-reduction works. Figure 11 is a chart showing the owned and affiliated companies of the Aluminum Co. of America, which indicates the extensive organization and ramifications of this concern and of the aluminum industry. In all, 75 companies are represented in the list. Considerable information regarding these various companies is given in U. S. Senate Document No. 67.[1] The total number of persons employed by the Aluminum Co. of America and subsidiaries is about 32,000 at the present time.

Aluminum Tariffs. No discussion of the aluminum industry would be complete without reference to the domestic aluminum tariff situation. In the United States, import duties on aluminum and manufactures thereof have been levied for many years. Under

[1] 69th Congress, 1st Session, Report on the Aluminum Co. of America, 1926, U. S. Government Printing Office.

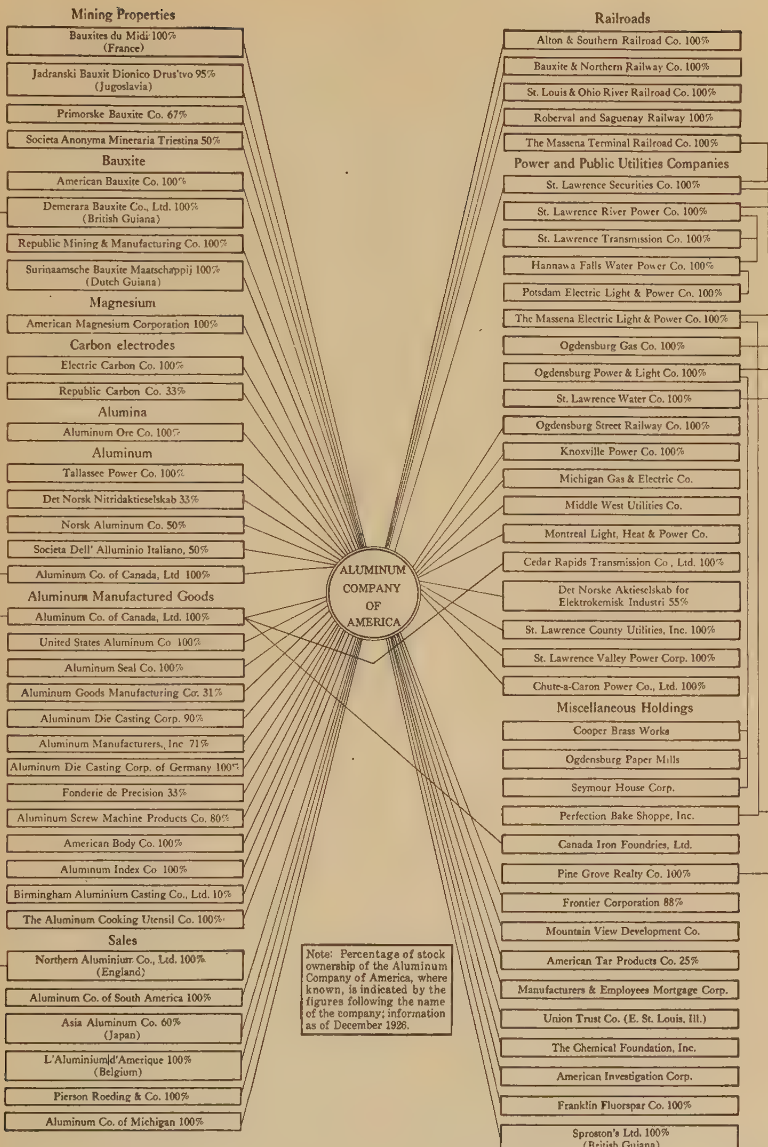

FIG. 11.—Aluminum Company of America. Relations of owned and affiliated companies.

the old Underwood-Simmons act, the import duty on aluminum, aluminum scrap, and aluminum alloys was 2 cents per pound, and that on sheets, coils, plates, bars, and related semi-finished manufactures was 3½ cents. Under the earlier Payne-Aldrich act, these duties were 7 cents and 11 cents, respectively. Under the present Fordney-McCumber law (of 1922), the duties are 5 cents and 9 cents, respectively. Emphatic protests are made regularly by consumers of aluminum and aluminum alloys, both individually and collectively, against import duties on aluminum pig, whenever this question comes up for consideration by the legislators. Needless to say, consumers, by and large, desire aluminum pig to be placed on the free list. Study of the tariff situation with regard to aluminum shows that the price of aluminum in the United States in the past has been increased in about the same proportion as the duty on foreign metal has been increased. The writer's views on the aluminum tariff, which is the most indefensible duty of the Fordney-McCumber act, have been clearly set forth in recent yearly volumes of *The Mineral Industry*[1] and elsewhere.

As opposed to the views of domestic aluminum consumers and various leading aluminum authorities, the Aluminum Co. of America demands a high duty as "protection against ruinous foreign competition." At the same time, the company argues that the tariff has no effect on prices and will even insure lower and more uniform prices in the long run. The reasoning by which this confounding conclusion is arrived at is based on the premise that with aluminum on the free list, the works of the company would have to shut down in the face of cheap foreign metal, and that then with the company ruined the foreign producers would raise their prices to unbelievable heights — so goes the plea as presented to the legislators in tariff hearings. Investigation of the arguments for protection against foreign competition shows that the plea of the Aluminum Co. of America is not borne out by the actual facts regarding competitive costs of production or volumes of output in the United States and abroad. During tariff hearings in the past, the Aluminum Co. of America has insisted over and over again with wearisome monotony that the duty has no effect upon prices. If so, why should the company, on the other hand, insist that it must have a high tariff? Whatever may have been the reasons which actuated foreign countries to impose import duties

[1] McGraw-Hill Book Co., New York.

on aluminum, it has been worse than a farce for the United States government to levy a duty on domestic imports of aluminum pig. The United States duties have lent effective support to the high prices which have prevailed for aluminum and manufactures thereof, and the domestic trade has yet to see the low prices promised by some experts and more particularly by representatives of the Aluminum Co. of America in testimony given before the tariff legislators in 1921 and previously. Briefly stated, the effect of the tariffs has been simply to raise the price of metal to the ultimate consumer. The dogma of supply and demand is an excellent rule and one that looks very nice in text books, but it is one that has never worked in the domestic aluminum industry due to monopolistic control by the Aluminum Co. of America.

During the latter part of 1923, the spectacle was offered of a presidential election campaign, in the United States, raging around aluminum and its tariff. A report of the Federal Trade Commission on domestic appliances and house furnishings brought out various allegations regarding the trade practices of the Aluminum Co. of America.[1] All the implements of good Democratic ammunition were at hand in the aluminum situation: (1) the metal being protected by a heavy and unnecessary tariff; (2) the industry being a perfect example of a monopoly; and (3) the Aluminum Co. of America, controlling the industry, being in turn controlled by the Republican Secretary of the Treasury, A. W. Mellon. The situation was seized upon by the Democratic party in October, 1923, as the basis for a savage attack on the Aluminum Co. of America and A. W. Mellon, in speeches of the most virulent and clownish character. The Aluminum Co. of America naturally denied all charges, and the discussion which ensued went on in a sort of vacuum so far as the general public was concerned — the latter setting the whole business down as politics. It would be a great error to underrate to the public the gravity of the aluminum monopoly, aggravated by a high and unnecessary tariff, but the Democratic party made a thumping mistake when it attacked the Aluminum Co. of America during a political campaign.

Importers can compete without difficulty with the Aluminum Co. of America despite the present high duty, since after the new duty was adjusted in 1922, the company raised prices in amount

[1] (*Vide* Federal Trade Commission's and Other Governmental Investigations of the Domestic Aluminum Industry, in the following section.)

to correspond approximately with the new tariff. Due to the change in duty from 2 cents to 5 cents per pound in 1922, there has been marked curtailment in the use of aluminum by the automotive industry, and because of the high prices prevailing in the past few years there has been considerable substitution of pressed steel parts for aluminum-alloy castings. There is a possibility that the Aluminum Co. of America will itself ask for removal or reduction of the domestic import duty when its new Canadian plant gets into large production. Or, rather, it is felt by students of the situation that removal or reduction will be effected by political maneuvers through the agency of the Democratic party. Those who are inclined to look into the tariff question at length as regards aluminum can do so by reference to government documents.[1]

German import restrictions are said to be measures to prevent dumping only. The government grants import permits for any genuine foreign offer which is more advantageous than home offers, if the home industry is not prepared to offer the same terms. One effect of this policy is said to be the protection of the German market from too high prices of the home industry. These import restrictions have been vigorously attacked by the German industrial press through complaint of founders and fabricators. It is clear that all applications for import licenses by consumers have practically to be referred to the producers, and the resulting situation is obvious. Import duties on aluminum and manufactures thereof are in force in France, Japan, Italy, and various other countries, including Spain and Belgium. French consumers, in particular, have been complaining of late regarding duties.

Under the tariff act of 1922, the import duties on aluminum, alloys, compounds, manufactures, ores, etc., into the United States are as follows: aluminum pig, scrap, and alloys, 5 cents per pound; aluminum sheet and related manufactures, 9 cents; aluminum-bronze powder, 14 cents; aluminum, granulated, powder, foil, etc., 12 cents; aluminum leaf, 6 cents per 100 leaves; aluminum cooking utensils, 11 cents; aluminum oxide (purified bauxite), $\frac{1}{2}$ cent; potassium alum and related salts, $\frac{3}{4}$ cent; aluminum sul-

[1] *Vide* Hearings on General Tariff Revision before the Committee on Ways and Means, House of Representatives, Part 1, Schedule C, 1921, pp. 896–928; and Tariff Information Surveys, Aluminum, Magnesium, etc., 1921; both of these publications obtainable from the U. S. Government Printing Office, Washington, D. C.

phate and related salts, with not more than 15 per cent alumina, $\frac{3}{10}$ cent; aluminum sulphate and related salts with more than 15 per cent alumina, $\frac{3}{8}$ cent; and bauxite $1.00 per ton.

Federal Trade Commission's and Other Governmental Investigations of the Domestic Aluminum Industry. During the past few years, the Federal Trade Commission has been investigating the trade practices of the Aluminum Co. of America, as well as those of numerous other domestic companies. As previously mentioned, the Federal courts found in 1912 that the trade practices of this company were in violation of the anti-trust laws, and the company was warned to discontinue these practices, which it promised to do. Owing to complaints by domestic consumers, strife centering about the tariff on aluminum, and the question of monopoly in the American industry, the aluminum situation has been given considerable attention by the Commission. In July, 1925, the Commission filed formal complaint (not made public until September of the same year) against the Aluminum Co. of America charging that the company is a violator of the laws against restraint of trade and monopolies. The gist of the findings of the Federal Trade Commission is contained in its Report on the House Furnishings Industry, Vol. III, Kitchen Furnishings and Domestic Appliances, dated October 6, 1924, which is the most distinguished contribution so far made to the enlightenment of the general public on the aluminum situation.

The complaint of the Commission, above referred to, charges substantially as follows, regarding the trade practices of the Aluminum Co. of America:

(1) Cancellation of customers' orders without warning or cause.

(2) Refusal to promise shipments after taking orders.

(3) Unreasonable delays in deliveries.

(4) In the case of sheet consumers making fabricated articles, where there are orders for several gages of sheet necessary to finish a given manufacture, one or two gages are delivered and the others held back so that the work cannot be processed to completion.

(5) After deliveries of metal have been unreasonably delayed, large quantities are dumped on consumers without warning.

(6) Deliveries of metal in large quantities are made to consumers on unreasonably delayed orders shortly after the purchase of foreign metal by consumers.

(7) Charging higher prices for pig or semi-manufactured aluminum to independent fabricators than to subsidiary companies.

(8) Discouraging potential competition in certain lines of the industry by refusing to sell pig or semi-manufactured aluminum to certain companies.

(9) Furnishing metal known to be defective and of poor grade.

In short, the Commission charges violation of the Sherman and Clayton acts. The Aluminum Co. of America denied all charges. It is naturally not surprising that the Federal Trade Commission should carry out an investigation of the Aluminum Co. of America. It is surprising, however, that this well-known monopoly should have been so long ignored. The point at issue in the controversy surrounding the Aluminum Co. of America is not whether the company is a monopoly; that is definitely settled. It is a matter of the utmost indifference to the American aluminum consumer as to whether the company is a monopoly or not. The point at issue is whether or not the Aluminum Co. of America has been conducting its business in such a manner as to be fair to subsidiaries and independent consumers alike. The answer to this, as indicated by the findings of the Federal Trade Commission, is No. On the other hand, the Department of Justice in an independent investigation states that the Aluminum Co. of America has not discriminated against competitors and has not violated the consent decree of 1912.

In February, 1925, Attorney-General Stone advised the Federal Trade Commission that the Aluminum Co. of America had practiced price control and violated provisions of the Federal court decree of 1912. In July, 1925, the Commission filed complaint, as stated above. In October, 1925, Attorney-General Sargent (successor to Stone) announced that the Department of Justice would not intervene in the investigation conducted by the Federal Trade Commission. Congressional inquiry of the company was launched early in 1926 by Senator T. J. Walsh of Montana and Representative W. A. Oldfield of Arkansas, both of the Democratic party. The Department of Justice made no move until the Walsh inquiry was announced, whereupon Attorney-General Sargent issued a statement whitewashing the Aluminum Co. of America. The Walsh inquiry provided columns of newspaper filler for many weeks during the first two months of 1926, and wound up as per expectations with the refusal of Congress to conduct an investiga-

tion of the company. Full details of the Walsh inquiry are to be had in the daily issues of the *New York World* for January and February, 1926. The attack on the Aluminum Co. of America by the Democratic party in 1926 had ample basis and may have been made in good faith, but the general opinion in the aluminum trade was that it was launched for purely partisan purposes to discredit the Coolidge administration. Independent aluminum consumers have watched the course of events too long to have any faith in governmental inquiry.

A notable case prosecuted by the Federal Trade Commission against the Aluminum Co. of America was that involving the Cleveland Metal Products Co., Cleveland, Ohio. This latter company built an aluminum-sheet rolling mill in 1915, purchasing foreign pig for processing. Shortly after the World War began, foreign importations ceased, and the Cleveland Metal Products Co. began purchasing pig from the Aluminum Co. of America. In 1918, the former company got into financial difficulties because it was obligated by contract with the Aluminum Co. of America for the purchase of a greater tonnage of aluminum pig than it could use in its rolling mill. The Cleveland Metal Products Co. then endeavored to cancel the obligation, but the Aluminum Co. of America would not agree. Finally, the two companies organized a third company in 1918, known as the Aluminum Rolling Mill Co., with a paid-up capital of $600,000 to purchase the rolling mill from the Cleveland Metal Products Co. The latter became owner of one third and the Aluminum Co. of America of two thirds of the stock of the Aluminum Rolling Mill Co. The Federal Trade Commission began investigation of the formation of this latter company, and in February, 1919, instituted proceedings against the Aluminum Co. of America. As a result of the action, the Commission ordered the Aluminum Co. of America to divest itself of its stockholdings in the Aluminum Rolling Mill Co. because of the violation of section 7 of the Clayton act, which prohibits, under certain conditions, the acquisition by one company of the capital stock of a competing company. The Aluminum Co. of America petitioned the courts for a review of the Commission's order, but, on June 1, 1922, the court sustained the order of the Commission and directed the Aluminum Co. of America to dispose of its two-thirds stock ownership in the Aluminum Rolling Mill Co.

The Aluminum Co. of America then sought to obtain consent

of the Commission and the courts to a modification of the order so as to permit the company, or one of its subsidiaries, to purchase the physical assets of the Aluminum Rolling Mill Co. at a dissolution sale. The Commission opposed such modification of the order, and this proposal was rejected by the circuit court of appeals. On August 13, 1923, the Aluminum Co. of America complied with the order of the court and sold to the Cleveland Metal Products Co. the two-thirds capital stock which it owned in the Aluminum Rolling Mill Co. Subsequently, however, the Aluminum Co. of America expressed its intention of purchasing the physical assets of the Aluminum Rolling Mill Co. at an execution sale. The Commission attempted to prevent this device for combining the two companies by applying to the circuit court of appeals for a modification of its order which would enjoin this transaction also, but the court denied the Commission's petition in an opinion rendered July 24, 1924, on the ground that the Commission had not proved that the indebtedness of the Aluminum Rolling Mill Co. to the Aluminum Co. of America, on the basis of the proposed execution sale, was fraudulent. This decision apparently has ended the controversy, and the property of the Aluminum Rolling Mill Co. is now owned by the Aluminum Co. of America.

During 1926, the Federal Trade Commission continued its investigation of the Aluminum Co. of America, which is still incompleted at the moment of writing. Whether this further investigation will lead to prosecution on the ground of violation of the Sherman and Clayton laws remains to be seen.

Competition in the Aluminum Industry. The Aluminum Co. of America is the dominant and controlling factor in the world's aluminum industry, and it is often claimed that control of prices throughout the entire industry is exercised by this company. Various agreements have been had in the past among the leading producers as regards markets and prices. It is often claimed that there is no competition at all in the domestic aluminum industry due to the monopoly held by the Aluminum Co. of America. There is, of course, actual competition in all branches, and a large independent industry has arisen in the United States. While the Aluminum Co. of America, enjoying a high import duty which restricts imports, does dominate the industry throughout, various domestic consumers import large tonnages of primary aluminum pig and buy nothing from this company. The independent

aluminum industry in the United States embraces a large number of sand founders, a small number of die-casting and permanent-mold-casting producers, a few sheet rolling mills, a number of powder and paint manufacturers, a few foil producers, a considerable number of utensil manufacturers, many stamping firms, a number of apparatus builders, and about a dozen fairly large secondary smelters. There are some 2,600 foundries and foundry departments of manufacturing plants in the United States in which aluminum-alloy castings are made. Most of these are small shops, but there are many large foundries having capacity of 1,000,000 to 10,000,000 lbs. of finished castings per annum.

There is ample scope for competitive producers of primary aluminum pig on the American continent, but there will probably never be any. Numerous projects have been announced from time to time regarding competitive aluminum producers in the United States and Canada, the more prominent of which have been those of the Anaconda Copper Mining Co., at Great Falls, Mont., in 1920–21, of Henry Ford, and of George D. Haskell. Experimental production of aluminum was made by the Anaconda Copper Mining Co. a few years ago, but this project came to naught. During the recent agitation regarding the disposal of the Muscle Shoals power plant by the government, Henry Ford was one of the bidders. When Ford was trying to get Muscle Shoals, supposedly for fertilizer manufacture, but actually for the production of aluminum, it was thought in the trade that the long-looked for competition in the producing end of the American aluminum industry was in sight. Ford was unsuccessful in his bid and is better off without Muscle Shoals, which is the most over-rated power site in the world and a mere incident in the Tennessee River development program. The total undeveloped water power in the United States worth developing is around 25,000,000 horsepower, that at Wilson Dam at Muscle Shoals amounts to 100,000 horsepower, and the probable total development possible on the Tennessee River is around 1,000,000 horsepower. There are better water-power sites in the United States, both developed and undeveloped, than Muscle Shoals.

George D. Haskell, president of the Baush Machine Tool Co., Springfield Mass., manufacturers of duralumin, had a tentative deal with the late James B. Duke, in which the two interests were to join in the production of aluminum at the Duke hydroelectric

power site on the Saguenay River in Canada. This particular power site is now owned by the Aluminum Co. of America, and the great Canadian plant referred to in previous paragraphs is being built around it. Haskell has filed suit in the Federal courts against the Aluminum Co. of America and the Duke interests for $15,000,000 damages (asking $45,000,000, or triple damages, under the anti-trust laws), alleged to have been suffered as a result of conspiracy to prevent him (Haskell) from getting the needed water power to produce aluminum, and of monopoly exercised by the defendants. Haskell's complaint states that he investigated bauxite resources and water-power sites with the object of producing aluminum, since he could not get deliveries to run his rolling mill and fabricating plant. Duke and Haskell entered into a joint undertaking for the production of aluminum. The Aluminum Co. of America then undertook to induce Duke to withdraw from the venture with Haskell. Duke then withdrew and would not proceed with Haskell. So much for the plaintiff's allegations. The Aluminum Co. of America, in answer to the complaint of the Federal Trade Commission stated in the preceding section, states that it has never done anything to prevent, embarrass, or hinder anyone from entering the aluminum production or fabricating field. Haskell's experience, as alleged, is one example indicating why domestic consumers of aluminum do not look for any producing competition on the American continent now or later. The case of the Southern Aluminum Co. has been previously mentioned.

News is continually being received of new interests taking up the production of aluminum in the United States, but if any group is really contemplating such a move or actually trying to produce metal, none has arrived at the commercial stage. Most information received concerning new interests in domestic aluminum production has consisted of, so to speak, half-baked details, which on the surface indicate that such interest will never produce any metal. The obstacles to entering the American aluminum-producing industry are, briefly stated, (1) that new interests fear that the Aluminum Co. of America will seek to restrain and intimidate potential competition; (2) that large financial resources are required, not only for plant and equipment, but also to carry on trade war and meet price cuts; (3) that practically all of the available bauxite resources, suitable for aluminum production, are controlled by the Aluminum Co. of America; and (4) that

there are relatively few technical men who know anything about aluminum reduction, and virtually all of these are in the employ of the Aluminum Co. of America; moreover, they are restrained by contracts not to divulge any technical information acquired while they were in the employ of the company.

European Aluminum Cartel. Through efforts of the leaders of the German aluminum industry, a continental aluminum trust was formed in the latter weeks of 1926, referred to as the European Aluminum Cartel. More or less close connection existed between some of the participants in this trust prior to its final establishment, and various agreements have been had between producers in past years. This new combination includes the German, Swiss, French, and British producers. The agreement includes about half of the world's production capacity for aluminum, the remainder being controlled by the Aluminum Co. of America. Press reports regarding the aims of the Cartel have been rather contradictory. The writer has recently been informed by several foreign correspondents closely in touch with the situation that the objects of the organization briefly include the stabilization of aluminum prices at £105 per ton, regulation of production, expansion of sales possibilities, division of markets, exchange of technical information, and concerted competition against the Aluminum Co. of America. Each producer is to be given a monopoly in its own market, and this is tantamount to the imposition of a high import duty in its effect upon the consumer. The seat of the Cartel will be at Neuhausen, Switzerland, and that of the executive committee at Paris.

The foreign producers are apprehensive regarding the future activities of the Aluminum Co. of America and especially fear the effects of the large production contemplated by this company at its new Canadian plant. In view of the apprehension continually expressed in some American political quarters and by the Aluminum Co. of America that Europe will over-run America with aluminum, the spectacle is now witnessed of Europe organizing to prevent being over-run by the Aluminum Co. of America. In 1925, a Berlin dispatch carried the information that the Aluminum Co. of America offered to purchase the entire capital stock of the German state-owned works and backed the offer with a threat that if the offer was refused, it (the Aluminum Co. of America) would invade the German market with prices far below those quoted in the United States. It is thought by some observers that the

Cartel cannot last long in its present form, and that it is simply regarded by the participants as an experiment, which will open the way to a closer association or admit of withdrawal. There has, of course, been hard competition for the markets in Europe, owing to the number of competing concerns, and at times the excess of supply over demand. It is expected that the European Aluminum Cartel will tend to correct the evils of excess competition abroad.

Labor Situation in the Industry. Labor enters into the production of aluminum and manufactures thereof at every stage from the mining of bauxite to the marketing of the finished products. While no reliable figures are available, it is estimated by the writer that the total wages earned by skilled and unskilled labor in the many branches of the American aluminum industry were in excess of $100,000,000 in 1926. This total is based on the estimated number of workers employed by the Aluminum Co. of America, by the independent casting industry, by the stamping shops devoted mainly to aluminum, together with workers in other plants, and the average wage per day. Numerous branches of the skilled labor trades are required by the aluminum industry in its various ramifications, and the industry is also a large employer of common unskilled labor. Workers in aluminum are not organized into any trade union similar to those in the different mechanical and building trades, and the aluminum industry in the United States is very generally operated as an "open shop." Union molders are employed in some aluminum-alloy foundries, but the casting branch as a whole operates with non-union labor.

As is the case with many other industries, many skilled specialty occupations have arisen in the aluminum industry, and it may take months and even years to train ordinary labor to become efficient in certain kinds of work peculiar to aluminum. Experienced operatives are highly essential to good work and low production costs in certain branches of the industry, notably in reduction, secondary smelting, sand and permanent-mold casting, and in sheet rolling. Workers for particular jobs are normally trained especially by the individual companies. There has been a general scarcity of reliable and skilled workers in aluminum since the inception of the industry in the United States due to the rapid expansion that has taken place. Moreover, there has been a great dearth of high-grade technically trained men skilled in the metallurgy of

aluminum for the supervision and management of plants. As a rule, little attention is paid to aluminum metallurgy in the engineering departments of universities and in American technical schools. The young metallurgical graduate may have some notion of the fundamentals of steel, lead, copper, or zinc metallurgy, but he has heard little about aluminum. The result is that the progressive company engaged in the production of aluminum manufactures must needs operate a school for teaching the basic principles of aluminum metallurgy to its men who hold the position of foreman or who may be in line for advancement.

Up to about ten years ago in the United States, the great bulk of the casting, rolling, stamping, and other working in aluminum and its light alloys was done in plants situated east of the Mississippi River and north of the Ohio River. In recent years, however, there has been a considerable expansion of the working-up industry into other parts of the country, notably on the Pacific coast and in small towns of the Central West. This has naturally created additional demand for labor and has resulted in the training of more men in aluminum work. This expansion has been a logical development with the increased use of aluminum in various sections of the country considerably removed from the great industrial section of the East. While most of the casting and fabricating plants are situated in, or very near to, large industrial cities, *e.g.*, Detroit, Cleveland, Chicago, Cincinnati, New York, and others, there has been a marked tendency of late to locate plants in small towns and rural districts not too far removed from the main industrial centers in order to take advantage of lower labor costs. For the past twenty years, about one half of the production of aluminum-alloy castings has been made in the Detroit and Cleveland districts, but of late Chicago has rapidly come to the front as an important casting center.

Labor problems in the domestic aluminum industry have not been difficult, barring a general dearth of skilled and reliable workers. Special training is required to develop skilled workers in other metals so that they become proficient in aluminum. Thus, an iron molder may have had twenty years' experience in the production of ferrous castings, yet it may take additional months before he learns how to mold aluminum-alloy castings successfully. Moreover, much of the knowledge he has gained in iron is useless, if not positively disadvantageous, to him in aluminum. Strikes

and labor disputes have been of infrequent occurrence in the American aluminum industry, although occasionally serious troubles have been had by aluminum-alloy sand foundries with the molders' union. Labor turnover in the industry as a whole is no worse than in many other industries, although in the years 1920 to 1923, inclusive, the turnover at the New Kensington plant of the Aluminum Co. of America ranged between 125 and 230 per cent with a total number of 3500 to 3700 men employed.

Wage scales for the different classes of skilled workers in the American aluminum industry have been considerably lower than for corresponding skilled workers in several other industries, *e.g.*, steel. This has been particularly true of reduction-pot operators and sheet rollers because they have had only one market for their services — the Aluminum Co. of America. The piece-work and bonus systems have been applied in the aluminum industry with considerable success of late years. The result has been lower production costs, higher quality work, better rewards for skilled and efficient operatives, and lower labor turnover. Thus, in the operation of reduction cells, efficiency depends not only upon the consumption of power and electrodes but also very largely upon the output of metal per cell per unit of time. One of the most important problems, then, of reduction-cell operation is to secure the maximum possible production from a group of cells. The bonus system has been tried with marked success by the Aluminum Co. of America in increasing the efficiency of reduction-cell operation. In the production of secondary aluminum alloys from borings and other fine scraps, profits depend in large part upon the volume turnover of metal and good recoveries from the scraps charged to the furnace. A system of payment has been tried with great success at one plant whereby the furnace men are paid a base rate per hour plus a bonus on tonnage produced plus a bonus on metal recovery above a certain minimum. In castings production, bonus systems and piece-work rates have been used in many plants to marked advantage as compared with ordinary hourly rates of pay. Present wages in the main classes of labor employed in the reduction works of the Aluminum Co. of America are given as about $5.00 per day. Molders in sand-casting and permanent-mold foundries earn upwards of $8.00 per day under the piece-rate or bonus systems.

The total number of wage earners employed in the American aluminum industry, including those on the pay roll of the Alumi-

num Co. of America, is upwards of 75,000 under good conditions of business. About 30,000 persons are employed by this company in skilled and common labor work. Some 20,000 persons are working as molders, coremakers, and foundry help in the independent sand-casting branch of the industry and as operatives in die-casting and permanent-mold-casting shops. About 15,000 persons are engaged in the stamping, rolling, and fabricating branch; and some 10,000 persons are employed in manufacturing plants such as vacuum-cleaner and washing-machine firms, aluminum powder and paint plants, in thermit welding, in secondary smelting plants, and by other concerns, the main business of which is aluminum and alloy manufactures. When the town of Arvida, the site of the new development of the Aluminum Co. of America in Canada, is completed, it is expected to house about 50,000 people, practically all of whom will be engaged in aluminum work or dependent upon this metal for their livelihood.

In passing, it is of interest to touch briefly upon the question of labor costs in aluminum production in the United States as contrasted with foreign countries, *e.g.*, Germany and Norway. It is argued by those in favor of a high duty on aluminum imported into the United States that the domestic production cost is much higher than the foreign cost due largely to the higher wages paid in America. It is true enough that domestic labor costs are much higher than those in continental Europe. On the other hand, it has been shown that any disparity in labor costs between the United States and Germany, France, or Norway is more than offset by the very high coal costs abroad. Roughly, five tons of coal are consumed by the aluminum industry per ton of bauxite used, largely for drying and calcination and various heating purposes in the preparation of alumina from bauxite. Coal costs in Norway are around \$25 to \$30 per ton. In Germany, under the administration of the state-owned reduction works, rather than discharge workmen from these "socialized plants," the policy is maintained of keeping labor at work with plants failing to make a profit and although the metal is sold at a loss. The German reduction works are subsidized by the government.

Resumé, Conclusions, and Forecast. A survey of the aluminum situation shows that this industry has expanded by leaps and bounds in a comparatively short space of time. The industry is still in its infancy but is growing with great rapidity. A continu-

ous expansion in the consumption of aluminum may confidently be expected, and the metal now ranks with the half-dozen metals most useful to the human race. The present output of somewhat over 230,000 tons per year is expected to reach 1,000,000 tons before 1950, while in net worth and usefulness aluminum is expected to be equal or greater than copper and be surpassed only by iron and steel. All the usual aluminum barometers point to sustained activity in the industry and a strong tendency to expansion. In the present discussion, it has been shown that the aluminum industry, in view of its large production and the rapidly growing range of new applications, must be considered as an important factor in international political economy. The romance of the aluminum industry has been blighted by harsher aspects of the subject, particularly in connection with strife centering around the Aluminum Co. of America. Aluminum producers, by and large, have been noted for their secrecy regarding processes, statistics, output, costs, and the general run of their business. This policy has been a destructive factor in the progress of the industry. The free interchange of ideas as to manufacturing methods and technical practice which is a prime necessity to advancement has been largely shut off. This policy has, however, undergone considerable change in recent years.

At the beginning of the twentieth century, the possible field of application of aluminum and its light alloys had been surveyed in a general way, and the uses for structural purposes were limited by the mechanical properties available in then known alloys. The development of heat-treatable aluminum alloys of about double the strength of those previously available served to enlarge greatly the field of possible uses. The chief factors which have served to alter the outlook for aluminum in recent years include the following: (1) the exploitation on a large scale of new bauxite fields, notably in the Guianas, and the discovery and prospecting of new fields, *e.g.*, in the Gold Coast and Nyasaland (Africa); (2) the discovery of the Hoopes process for the manufacture of *pure* aluminum; (3) the commercial application of heat-treatment processes to various aluminum alloys, both cast and wrought; (4) the marked increase in consumption at home of certain European producing countries (notably France); (5) the greatly broadened field of use for aluminum and its light alloys, owing to increased number of applications and their substitution for cuprous-

and ferrous-alloy parts; and (6) the more favorable outlook for aviation. The general broadening of the field of usefulness of aluminum is highly desirable not only from the point of view of the producer but also the consumer, since this stabilizes the market and steadies the demand. It is poor business to have the bulk of production of a given commodity taken by one consumer, and efforts have been steadily made by producers to widen the field of aluminum consumers. The chief factors which have served to alter the outlook for bauxite include the following: (1) the general increase in the production of aluminum and widespread interest in new aluminum plants; (2) the opening of new mining fields and the discovery of others; (3) the rise of the aluminous-cement industry; and (4) the development of new uses and increases of old uses for the mineral. The world's aluminum industry was badly depressed in the post-war slump, and the total output of primary metal declined from 200,328 metric tons in 1918 to 74,874 tons in 1921. The output has, however, been substantially increasing in the past five years.

A survey of the aluminum industry proves, or at any rate argues very cogently, that aluminum will remain at an unnecessarily high price until there is competition in the production end in the United States. It has been suggested by some that the price of aluminum would be lower if the output were greater, and comparison has been drawn between the total production of copper and that of aluminum as indicating greater stability in the copper industry and the reason why some consumers prefer to specify copper and cuprous-alloy parts instead of aluminum and its alloys. There is something to be said for the latter comparison, in that it is one of the reasons why aluminum cable has not more extensively replaced copper for transmission purposes, and why large consumers hesitate to change to aluminum from copper — in short, they fear that the supply is not large enough. The general policy of commodity producers in this country is to develop consumption by enlarging and cheapening production, which is a sound policy, greatly to the advantage of both producer and consumer alike, as has been shown in the copper, steel, lead, zinc, rubber, automobile, moving picture, foodstuffs, and other basic industries. It has been suggested that a greatly enhanced output of aluminum might not find a ready market even at a much lower price, hence producers wisely keep the output at a restricted level.

A much larger output than that at present would doubtless not find a ready market at the current price, but with the present actual and potential demand the producers could figure on a 100 per cent increase in consumption at 20 cents per pound. The writer is of the opinion that with aluminum at 15 cents per pound the world could easily absorb 2,000,000,000 lbs. per annum.

That the high price of aluminum is the main restrictive factor in the more widespread use of aluminum and its light alloys is plainly shown by the attitude of the American automotive industry. The use of aluminum in the American motor car has been steadily falling off for a number of years, and American makers are far behind the European in the employment of the metal and its light alloys in automotive construction. The total amount of aluminum consumed in the domestic automobile industry today is no more than it was five years ago, when about 120,000,000 lbs. were taken. Even in some of the higher grade cars, cast-iron crankcases are being used instead of aluminum-alloy cases. The explanation offered by the leading manufacturers is that the metal is too costly despite its advantages, and the sources of supply are too uncertain in the face of the large excess of demand over supply, and that they cannot take the chance of being cut off in the midst of production. If American automobile builders used as much aluminum per car as European builders, the consumption of aluminum by the automobile industry would be greater than the present world production of this metal. A high tariff on aluminum can have one of two effects in the American automotive industry: (1) it can mean higher-priced motor cars, because of the higher cost of aluminum, or (2) it can mean a lessening of the use of aluminum and aluminum-alloy parts, thereby decreasing the efficiency and quality of the American motor car. There were widespread misgivings in the trade when the duty on aluminum was raised from 2 cents to 5 cents per pound by the Fordney-McCumber act, because the natural corollary to a high duty is a high price to the ultimate consumer. Domestic consumers of aluminum, as well as those in foreign countries, have been sorely harassed by unnecessarily high tariffs, and the legislators would do well to devote some time to a sensible consideration of aluminum — a prime requisite for aircraft and war.

The aluminum industry is interested in the widespread and unprecedented development of hydroelectric power projects all over the world, which is expected to presage large use of alumi-

num cables for transmission lines. Electrification of railroads has been numerous also in recent years and of importance to cable makers. The entry of Henry Ford into the aircraft field introduces a factor which may be of great importance so far as consumption of aluminum is concerned. Each of the Ford all-metal planes requires about 1,600 lbs. of aluminum and aluminum alloys, and if the aircraft industry should develop only a small percentage of the growth which has occurred in the motor-car industry, a large consumption of aluminum would be taken. Generally increased activity in aviation has been witnessed lately which is expanding in commercial lines. Regarding possible competition in the production of primary aluminum on the American continent, in view of the history of the industry actual performance must precede any faith in new competitive companies. In annual reviews of the aluminum industry published yearly by the writer in the American Metal Market, the most important developments of the successive years are discussed together with their bearing on the future, and the production and consumption tendencies are indicated. In addition, the more noteworthy features of current progress are discussed with a view to giving producers and consumers a basis for judging the future outlook.

In the United States, the production of aluminum has grown from about 40,000 lbs. in 1890 to around 200,000,000 lbs. in 1926. As shown by statistics, the rise of the aluminum industry has been amazing, but the technical developments have been even more so. As indicative of what may be expected in the future, it is of interest to recall that the world production of aluminum has increased by about 100 per cent for every five-year period over the previous five-year period from 1900 to date. The world output in 1930, reckoned on this basis, would approximate 400,000 metric tons, and such production would require about 400,000 tons of carbon electrodes, 800,000 tons of alumina, and 1,600,000 tons of bauxite.

CHAPTER II

THE AUTOMOBILE INDUSTRY

By A. R. Erskine[1]

Introduction. No industry has a larger place in public attention than the automobile business. It is one of the several essentials in modern civilization and it has the added news value of novelty.

For centuries, perhaps since the beginning, man has had his individual home, his family table, and his personal wardrobe. It is true that in the horse and buggy he had personal transportation, but it was not satisfactory. Few human beings care for hotel life as a permanent matter, few would choose a general boarding table as their ideal, and getting one's clothing from the army quartermaster is a procedure which is satisfactory to most people only in time of war.

Our first successful rapid transit accommodations were communal. This moving of masses of people and masses of freight over railroad lines has its advantages and fits in as a valuable part for our economic scheme. As soon as the automobile became a practical means of locomotion, however, the instinctive human desire for individuality began to assert itself. The phrase — " once a car owner always a car owner " — is an important psychological and economic statement. The individual wants his own car as intensely as he wants other intimate personal possessions. It represents to him a personal freedom which is of even more value to him than the general recreational and economic benefits he may receive from it. That is why the automobile industry has increased from a wholesale value of approximately five million dollars worth of production in 1899 to more than three billion annual production in 1926. These figures represent simply the wholesale value of cars and trucks and do not include the

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allied products such as repair parts, tires, accessories, gasoline, oil, and other items dependent upon motor transportation.

The automobile industry is listed by the Department of Commerce as being the largest of the country's manufactures. Registration of motor vehicles has been increasing at the rate of about two million units a year. This means that that number of cars has found new markets, while the balance of the production has gone to supply old buyers or into foreign trade. A large percentage of automobiles are sold today to people who are already automobile owners, but where a new car is sold to an old owner there is likely to be an old car taken in trade; and the second-hand car in turn is sold to a man who may be a first-time buyer.

Two outstanding elements in the business today are the increase of the two-car family and the opening markets of the overseas business. There are close to three million families in the country today who own more than one automobile. With the large number of efficient low-priced cars on the market, the tendency in all but the largest cities is for each adult member of the family to have his own car. The chief resistance in the large cities is the problem of garaging. Present-day practice in the building of suburban homes is to provide two-car garages rather than the old-fashioned single vehicle type.

There are some people who feel that the crowded congestion of city streets and highways is a blockade to future extension of automobile transport. The problem, however, is not so much a matter of new street space as it is efficient use of existing street areas. In many cities important avenues are much reduced in their carrying efficiency because they include dead-end streets at the outskirts of the city, or because they have heavily traveled intersecting highways which should be separated by overpasses, thus giving a maximum flow of traffic on each one.

Overseas business is going forward rapidly. It faces the problems in many cases of poor highways, high taxation, and low purchasing power. Nevertheless, there are signs everywhere of a different attitude toward transportation which can do away with most of these difficulties.

Europe is coming increasingly to machine power, recognizing that that is one of the major solutions of her ills. This tendency toward the use of machinery to increase the efficiency of man will bring with it a wider recognition of the value of motor transport, not

alone for personal use but also in freight service in opening up great areas which are rich in natural resources.

The purchase of American automobiles abroad has been going forward rapidly. In 1923 other countries bought 329,000 American vehicles, in 1925 this total had increased to 525,000, and in 1926 the figure was 487,000. There will doubtless be year-to-year ups and downs, but the general curve will climb higher. It is the opinion of the automobile industry that within a few years we shall be exporting a million cars annually, and that ultimately the figure will be much larger than that.

So extensive are the ramifications of motor transportation that the best way to treat the subject clearly is to consider different branches of it, such as commercial vehicles, its effect on other industries, its relationship to highways, the development of the car mechanically, and the problems of regulation.

I have refrained from giving here statistics of the number of passenger cars in use, monthly production totals, and general statistics because these are published currently by the National Automobile Chamber of Commerce and reprinted widely in many publications. In considering the automobile industry as a whole in a volume which has aimed to serve the purpose of reference, it seems more pertinent to discuss the trends and outlook as I have endeavored to do, and then to outline the various correlative aspects which I have suggested.

Commercial vehicle growth. Within the last two decades the motor-truck industry has grown from a side-line activity of passenger automobile manufacturers to an industry producing annually, in more than one hundred and seventy-five exclusively commercial motor vehicle factories, a total of approximately 500,000 trucks and busses having a wholesale value of more than four hundred million dollars.

The motor-bus industry, developing in turn from the motor-truck industry, has grown within the last decade until today there are more than eighty factories, many of them also devoted to truck manufacture, which produced in 1926 approximately 13,500 busses.

The motor truck met its first real tests and began to be extensively developed during the late war. Operations were at that time carried out on such large scale that every available means of transporting both men and supplies were pressed into service.

The mobility of the motor truck as compared with carriers operating on rails led to the use of the highway vehicle to the greatest possible extent, both immediately behind the battle line and also in speeding up the manufacture and delivery of military supplies.

The greater utilization of trucks at that time was due not only to their greater mobility but also to the fact that railroads were so overburdened with shipments that an alternative means of transport had to be found if many kinds of commodities were to be moved at all.

In adapting the truck to the severe service to which it was then put the makers of those vehicles rapidly developed machines that would stand up under the rigorous demands made upon them.

So great was the impetus which the war gave to the development and extensive use of trucks that the years following that conflict have witnessed the gradual acceptance of motor trucks as established carriers along with steam railroads, electric railways, and waterways. Large and small industries and business houses as well as farmers all over the country have added to the truck equipment which they put into service in the transportation emergency caused by the war, or have begun to use motor carriers for the first time.

The motor bus as we know it today was practically non-existent ten years ago. Such so-called busses as existed at that time were largely converted trucks. Those makeshift vehicles consisted of truck chassis upon which were mounted rigid bodies with comfortless seats for passengers. These vehicles served in their early days chiefly as carriers of sightseers in cities, and, up to the last few years, as uncomfortable yet oftentimes convenient means of reaching points distant from other transportation lines.

Encouraged by the eagerness of the public to use these new carriers in spite of the discomfort that they caused, engineers of numerous truck companies recognized that a vehicle for the carriage of passengers should be built along lines distinct from those of the truck, and began to develop busses that were especially adapted for carrying passengers over the highways in comfort.

With the development of serviceable and attractive busses, lines sprang up in large and small cities and between cities all over the country. This increased use of busses in both congested centers and along country highways led to a further recognition by those concerned with bus development that each type of service required

a special type of vehicle. As a result there were developed the so-called street-car, intercity, deluxe suburban, and de luxe touring busses with which we have become familiar.

Both the truck and bus have grown in public favor in the last few years until today they are firmly established and vital units of our transportation system, with more than 2,750,000 trucks and 80,000 motor busses engaged in the movement of property and passengers at the beginning of 1927. These vehicles, together with private passenger cars, are operating over three million miles

Fig. 1. — Busses are opening up suburban territories.

of rural highway, of which 500,000 miles are improved, in addition to the paved streets of our cities, as compared with the 250,000 miles of track to which rail carriers are confined. These three types of motor vehicles all together represent an investment of twenty-five billion dollars, which equals the present investment of railroads in equipment.

So clearly has the motor truck, both gas and electric, proved its superiority to the horse-drawn vehicle for city hauling, that today horses have largely disappeared from the streets of large centers of population, except near the most severely congested terminals of our largest cities, such as New York and Chicago.

The same revolution has taken place on rural highways, until today almost all of the hauling over highways in many states is

done by motor truck. The deciding factor in this transformation has been the saving in time which the motor truck makes possible and also the greater operating radius of the motor vehicle. An investigation by the United States Bureau of Public Roads showed that it requires only approximately one third as much time to make the average round trip of a farmer with a truck as it does with a horse-drawn vehicle carrying the same size load.

Other investigations by this Government Bureau have revealed that the motor truck has in its years of adaptation found its distinctive field of service to be in short-haul areas where pick-up and delivery service are essential. It was shown that the commodities hauled are primarily foodstuffs and perishables, these constituting about 40 per cent of the total truck tonnage. Other important commodities hauled are building materials, gravel, crushed stone, and lumber. The great bulk of the commodities moved by truck were carried for distances of 30 miles or less.

FIG. 2.—Forty-five million head of cattle were hauled to the main packing centers by motor truck in 1925.

Such so-called long-distance hauling by truck as takes place is in the nature of specialty carrying, such as the moving of furniture, where directness of delivery and avoidance of crating make it worth while, or of commodities of slight bulk which require speedy delivery, regardless of cost.

Of the 80,000 busses now operating, approximately 36,000 are used in transporting pupils to consolidated schools in rural sections and in carrying passengers to hotels and on sightseeing tours. All these operations are of a non-common carrier nature.

The remaining busses are engaged in carrying passengers for hire over scheduled routes and between fixed termini. The majority of these vehicles are operated by highway transportation companies, organized expressly for that purpose. Many of these operations have reached a high degree of efficiency in a very few years, operating luxurious coaches equipped with every convenience for the comfort of their passengers, and maintaining terminals which compare favorably with those owned by older transportation agencies.

Next to the independent operators, the largest group using busses in common-carrier service are the electric railways. These older carriers began to feel the competition of motor busses in the years immediately following the war, and after unsuccessful attempts to prevent their operation in competition with their rail lines, began to study the possibility of operating busses themselves.

A few electric railway companies began experimenting with bus operating, and in 1921, sixteen such companies were operating 73 motor busses. The success of those experiments led to the rapid installation of busses by railways all over the country, until in January 1, 1927, there were 266 trolley companies operating 7284 motor busses over 13,619 miles of route, as auxiliaries to their rail operations. So successful did the busses prove in reducing losses incurred in the operation of electric cars on poorly paying lines, that in September, 1926, there were 43 traction companies operating 193 buses over 404 miles of route in localities where street railway service has been entirely abandoned.

Next in importance to the electric railway group in the operation of busses are the steam railroads. These carriers also saw their passenger revenues decrease with the advent of the bus and tried with little more success than the electric railways to suppress the highway carriers. Failing in this and observing how electric railways were meeting this new competition, a few steam lines began rather timidly to experiment with the operation of busses.

The results of these experiments having proved that the bus, while it could not always, when used in place of non-paying local trains, turn a loss into a profit, could often reduce losses, other

railroads began to operate busses over the highways. This movement has grown in the short space of three years until today 60 railroads or their subsidiaries are known to be operating at least 756 busses. Other railroads have made arrangements with motor-carrier lines under which passengers may travel by either rail or highway over specified routes.

Of the railroads using busses, fourteen are operating them over highways paralleling their real lines. In this way those railroads are meeting motor-bus competition on its own ground, and are also rendering more frequent service than they could afford to give with their rail equipment alone. At least six railroads have discontinued service altogether on some of their branch lines which have been made unprofitable by a decline in traffic. As they are required by public regulatory bodies to render service to points along those lines, they have resorted to motor busses in order to meet the requirements of the public and at the same time greatly reduce their losses from such service. In fact, so successful have busses been in paralleling or substituting for existing rail lines, that four progressive steam carriers have started operating them to points never reached by rail. These new highway lines give service to new sections and act as feeders in providing more passengers to be carried over the rails.

One kind of feeder service which has just been tried out and which may be expected to become more prevalent with the increasing concentration of large numbers of people in cities, is the operation of busses between convenient waiting rooms in the heart of a city to railroad terminals located beyond the congested area. Such a service was instituted by the Baltimore and Ohio Railroad last summer, when 22 busses began carrying passengers from waiting rooms in New York City and Brooklyn to its train terminal in Jersey City.

Even before steam railroads began to use auto busses some of them had recognized that the motor truck could be utilized to good advantage in the handling of freight. The services to which they were found to be adapted are the handling of less than carload lots of goods and the transferring of commodities at terminals. The New York Central and the Pennsylvania railroads were the first to substitute motor trucks for local trains carrying package freight. They found that by eliminating their so-called "peddler" freight trains they would be able to speed up through shipments.

This elimination was accomplished by designating certain points as zone stations and by shipping all goods consigned to intervening points to them. Motor trucks were then used to carry this L. C. L. freight from the zone stations to the intervening stations at which freight trains formerly stopped.

Of 52 railroads using trucks in one way or another eleven employ them in the replacement of local freight trains, with the result that both L. C. L. and carload shipments have been speeded up to the profit of the railroads, the shippers, and the consignees. The pub-

Fig. 3. — Forty-six railroads use motor trucks in terminal operations, fifteen for store delivery, and eleven to replace local freight trains.

lic is also benefited in that orders can be filled more rapidly, resulting in lower inventories for merchants, which tends to be reflected in lower prices to consumers.

But, valuable as the truck has proved as a substitute for local freight trains, it has been and is being used most extensively in operations around terminals. In this field trucks serve as extensions to rail lines in carrying goods not only between terminals located in the same city but also between terminals and the doors of consignees and shippers. The largest terminal-to-terminal operation in this country is in Cincinnati, where 23 railroads, faced with the necessity of spending $12,000,000 for enlarging their existing terminal facilities to relieve congestion, decided to organ-

ize a coöperative terminals company and spend $150,000 for trucks, 200 demountable bodies and lifting apparatus instead. By the use of these demountable bodies or containers, which can be carried on railroad flat cars as well as motor trucks, handling, charges, time required, and terminal overhead have been greatly reduced. Package freight is loaded into these containers, which are then mechanically placed on 5-ton trucks and routed to another station by a dispatcher employed jointly by all interested railroads. A way-bill is delivered with each sealed container, and a receipt is given to the truckman in exchange when he leaves his loaded container at its destination.

At St. Louis and East St. Louis the Columbia Terminals Company, acting as agent for all railroads reaching those points, operates a system of off-track freight stations and a large number of tractors and semi-trailers which operate between its off-track stations and the terminals of the railroads. This company when notified by shipper or consignee that delivery of an inbound shipment is to be made by means of its equipment, sends a tractor and trailer to the railroad terminal where the freight has been received and it is carried to the company's inbound station most conveniently located with respect to the address of the consignee. The consignee is at once notified of its arrival and, if he requests it, may have the shipment delivered to his door by the terminal company at a reasonable rate. He also is entitled to leave his shipment with the terminals company for 48 hours, if he desires, without charge for storage. The railroads are in this way afforded what amounts to an extension of their lines into the principal business and industrial districts of St. Louis.

Similar service is offered shippers and consignees in New York City by the Erie, the Pennsylvania, and the Lehigh Valley railroads, which through contracts with the United States Trucking Corporation are in a position to offer speedier and cheaper handling of shipments than was formerly possible at their badly congested terminals on the Manhattan waterfront. The trucking corporation maintains five large inland stations on the ground floors of its warehouses, and its trucks carry inbound and outbound shipments over the Hudson River ferries between these stations and the Erie, Pennsylvania, and Lehigh Valley freight terminals in New Jersey. All freight originating in New York City and destined for these railroads is brought to these inland stations, where it is sorted

and made into truck loads for haulage to the proper New Jersey terminal.

In these ways the motor truck has brought valuable elements of speed and flexibility into the transportation of commodities, just as the motor bus has accomplished this in the transportation of passengers.

Railroad and Insurance Companies Gain from Motor Transport. In perhaps no other instance is the support given other industries more marked than in the case of the railroads. Where a decade ago there was no shipping of automobiles and parts, the Interstate Commerce Commission's Commodity Statistics for 1926 indicate 889,778 carloads. Adding to this the shipping of gasoline, lubricating oil, tires, iron and steel, road-building materials, and similar freight that is due to the manufacture and use of automobiles, a grand total of 3,280,000 carloads is estimated.

But even this does not include road-building machinery, materials for the construction of factories, sales rooms, garages, service stations, and the tremendous amount of less-than-carload freight and express shipments of accessories and repair parts on which there are no statistical records.

Railroad participation in the industry's operations traces back into shipping of raw materials such as ores and semi-finished materials and accessories to an extent impossible of exact determination.

The 3,743,000 employees in the industry are all served by the railroads in the way of foodstuffs and necessities. As one writer recently stated it, this represents about 10 per cent of the population, making it apparent that about 10 per cent of general railroad traffic is now due to the motor industry.

Similarly, in the insurance business the total automobile liability, collision, property damage, fire and theft and full coverage on automobiles amounted to $428,088,202 net premiums. Against this losses paid amounted to $206,500,359, not including agents' commissions, home office and operating expenses. This represents a tremendous turnover with accompanying activity and profits to insurance companies and their agents.

Highways and Motor Taxation. The largest single problem involved in developing the use of the motor vehicle is the question of providing adequate facilities in the form of improved highways. Not alone is this a matter of moment to the individual who drives the car, but the social, economic, and political reactions are imme-

diate and far reaching in their effect. Assistant Secretary of Commerce, Mr. J. Walter Drake, said recently that there are some 45,000 communities in the United States which rely solely upon the truck and the bus for their transportation.

The improvement of roads to these communities, as he points out, places them on the railroad lines of the country and, far more important, brings them into direct contact with each other. The effect of road developing upon education has been very marked. "The large amount of road construction which is under way,"

FIG. 4.—Home-going traffic in a modern city.

says Dr. Abel, of the United States Bureau of Education, "has been one of the strongest factors in making school consolidation progress more rapidly than it has before."

The social and economic necessity for road development from the farm viewpoint has been so frequently stressed, not only by government officials and economists, but by members of the leading farm organizations, that it need not be dwelt upon here, save to point out that it is the road and the motor vehicle which have broken down the traditional isolation of country life. The further value of roads as an agency in periods of national emergency has been testified to by General Pershing, who said that without roads neither armies nor their supplies could be moved.

" The dominant note of life in America today," says Stephen T. Mather, of the National Park Service, " is the evident desire for outdoor living and recreation. The development of the motor car and the expansion of good roads have helped to bring this within the reach of the average American, as well as the rich man." At the present time there are some 3,000,000 miles of highways in the United States, of which some 521,915 are improved to varying degrees.

In 1926 there were 35,000 miles surfaced and it is anticipated by road authorities that approximately this rate of improvement will have to be maintained for several years in order to provide a system adequate to care for the constantly growing transportation needs of the country. Because of the universal demand for road improvement, because of the cost involved, it has been necessary for the road authorities of the country to select those highways which are of the greatest importance and to improve them first. The administrative procedure now followed may be briefly summarized.

Under the terms of the Federal Aid Act, first passed in 1916 and amended in 1921, the several states were required to set up Highway Departments as prerequisites to monetary assistance from the government in developing their highways. The second step involved the selection of the roads to be improved. Under the terms of the Act, Federal funds can be expended first upon that 7 per cent of the total number of roads in each state which are determined to be the most important roads in the state and which serve not only to link up the principal points of population within the state, but also to join with the roads of other commonwealths at boundary lines. The total mileage contained in the system so selected is 200,353 miles, of which 56,717 miles, or 23 per cent, have now been improved. Of the remaining mileage, 69 per cent has been approved for construction, while 8 per cent yet remains to be both approved and constructed. The law further provides that upon completion of the improvement of this 7 per cent Federal funds may then be used upon roads which would comprise an extension of the system. Three states, Delaware, Maryland, and Rhode Island, have completed their original systems and are now devoting Federal funds to extensions.

Appropriations for road improvement have varied under the Federal Aid Act from year to year, but at the present time they

are stabilized on an annual amount of $75,000,000. This is divided among the several states upon a formula based upon area, population, and mileage of roads. All the states except those having large areas of public lands are required to meet the Federal appropriation by the appropriation of at least an equal amount, but in practice the state funds have usually been about three times that of the government. In the case of the public land states the formula varies, and in some cases the government funds now amount to practically the entire appropriation for the improvement of small mileages.

With the exception of the work which has been done in the forest roads, National Parks, and Indian Reservations, the Federal government does not enter the field of construction, the actual work of road building being left to the states. However, strict standards are set up, and all projects must be finally passed upon under government inspection before Federal funds are paid out.

In each case the method is left to the state with the provision that if any state fails to maintain a road properly, its portion of Federal Aid must be devoted to improvement of roads already constructed with Federal funds before any other use is made of it. While the Federal Aid system is comprised of roads which are most important from the standpoint of the volume of traffic over them, there are many thousands of miles of roads outside of the system, the improvement of which is of immediate consequence to the states and the localities.

The states usually take the Federal systems as the basis for their main state highways and add to this a selected mileage of roads important from the state but not the interstate viewpoint. These roads are then constructed from funds which are derived either from state bond issues, general state appropriations, or from funds supplied by the counties through which the road passes or through the agency of special taxes such as the levy on motor registration fees and gasoline. Sometimes the state grants aid to the counties in much the same way as the Federal government does the state. Approximately 250,000 miles are under the direct observation of State Highway Departments and this figure is tending to grow as the use of the vehicle increases.

The third in the administrative controls of highway improvement is the County Board, which has jurisdiction over the roads in the county units. Approximately half of the billion dollars annually

devoted to road improvement is expended under the direction of these boards and in the constant construction and maintenance of the so-called secondary roads.

Because of the fact that the units are smaller and because there has not been the same recognition of the need for selection of the system, the roads in the counties are not always as well coördinated with other highways as they should be, nor are they fully maintained. The extension of engineering administration, however, is gradually pointing the way to better practices in this field, which comprises by far the largest percentage of the total mileage of

FIG. 5. — How the modern dairy farmer delivers milk to the city.

highways but which necessarily does not handle the same volume of traffic as the roads to which the county highways are feeders.

Finally there are the township, district, and municipal units all of which are independent jurisdictions, charged with the improvement of local roads, and deriving their funds from local taxes of one sort or another, usually based on property valuations.

In the early stages of the development of the highways the practice was to build roads through tolls levied upon the user, or through taxes levied upon cities and usually paid in the form of labor. The irritation caused to the user and the lack of adequate maintenance led to the abandonment of the toll system, and gradu-

ally the practice of paying a man to do the labor was evolved from the poll tax method.

With the advent of the motor vehicle there came a recognition of the fact that road improvement constituted a general benefit which should be participated in by all, and the states turned to bond issues as the most adequate means of expediting improvement. This method proved highly successful, the more so because in the deferment of cost until the completion of the road the state had time to reap the fruits of transportation and increased land valuation and hence created the funds for the improvement out of the work itself.

In the early stages of motor vehicle development the only special taxes paid by the owner were fees for license plates, which were developed as a means of enabling the police to regulate traffic. As the road user, however, grew in number his demand for roads became more insistent. Recognizing that he obtained a special benefit from road improvement not only in lowered transportation costs, but also in the ability to use the car more generally, the user himself accepted the principle of taxes upon the car for use in road development.

From this beginning there has grown the practice of registration fees and gas levies, which today are generally applicable to motor transportation in the United States. Broadly speaking, motor vehicle taxes may be divided into two classes: those which are general in character and contributed only in the same proportion which other taxpayers pay, and those which are special in nature and contributed only by the owners of the vehicle, presumably in return for a benefit in the form of improved highways.

Under the first heading come such levies as the Federal income and corporation taxes, the general state taxes, such as the income property taxes, and those other levies which fall upon all business. With few exceptions, the extent of these levies has never been determined, primarily because both the users and manufacturers of the vehicle have always accepted the principle that they should share in the burden of taxation to the same extent as any other group of taxpayers, secondarily because the cost involved in a searching analysis would be prohibitive.

A few of the examples of these general taxes may serve, however, to indicate the extent of general contributions which are made today either directly by the owners of the 20,000,000

motor vehicles now in service, or indirectly in the form of cost of service.

Possibly the largest item is property taxes levied upon the garages, filling stations, repair shops, and other properties incident to the use of the vehicle. This will vary from zero, in the case of the owner who simply runs his car on to a vacant lot, to large amounts paid on the elaborate investments now found in city stations. Many of these groups pay as well Federal, State, and Municipal stock, income, corporation, and business license charges.

Another large expenditure is that paid in the form of general taxes by organized companies engaged in the business of highway transportation. These companies vary in nature from the individual doing a small trucking business to the highly organized freight and passenger company. They include coöperative hauling groups organized by farmers, particularly in the livestock, truck, and dairy fields, fleets operated by large industrial units such as oil companies, meat packers, and telephone companies, and the delivery units of the retail houses. In their list will be found also the commercial trucker, the contract carrier, the private hauler, and the growing units operated by steam and electric railway lines in both the bus and truck fields. In all of these and many other cases, even cursory examination will show that returns must be made for all the taxes collectible as general levies according to the extent of the business.

If a full search into the incidence of motor taxes were made, the levies could be traced back to those charges made against the manufacturers of the vehicles, and of their component parts. No effort has been made to do this, however, save in the case of the Federal excise taxes. That studies have been made of these is due to the fact that not only are these charges passed on directly to the consumer by the manufacturer and listed as taxes in the invoice of sale, but they constitute also a special and discriminatory levy not common to all business. In effect they constitute a super-tax since they are paid in addition to the customary levies.

Although the extent of these general taxes is not known, it is only necessary to examine the general trend of taxation as a basis for the statement that the increase has been rapid and large in amount during the past decade.

The field of special motor vehicle taxation has been much more closely surveyed and consequently there is a much more accurate

conception of it. In 1926 the special Federal, State, and local taxes paid by the motor vehicle users of the United States amounted to $587,000,000.[1] In addition they paid another $125,000,000 in personal property taxes, which have gradually come to be recognized as a form of special taxation since the vehicle has come to be regarded as an element in transportation such as rail equipment rather than as a matter of household equipment. Of this amount it will be seen that about $96,500,000 was paid to the Federal government, $600,000,000 to the states, and $15,000,000 to the municipalities.

While these figures are reasonably so, they are not entirely conclusive, particularly in the field of local taxation where innumerable forms of levies have been devised to secure revenue from the motor vehicle owner.

A detailed list of many of these levies is shown on page 92. It is sufficient to note here that there are eight principal special taxes levied against the passenger car in most states today, while the list of special taxes on trucks, busses, and taxicabs reached fourteen varieties even where the franchise tax is not listed, since it is applicable to other transportation carriers as well. In the detail of application, these taxes carry the student through an amazingly intricate and diversified series of formulæ presenting no standard of uniformity either as to amount or as to factors employed in determining the amount.

The registration fees vary in different states, but regardless of the average charge there is almost uniformly a differentiation made between types of vehicles. Thus the charge is usually lower per unit on the small passenger car or truck than on the vehicles of heavier capacity, and the rate of progression grows with the size or weight of the vehicle. There is a sharp and general differentiation as between the passenger car and the motor truck, the charges for the latter being uniformly higher. Thus, as a glance at the government tables will show, in the thirty-three states and the District of Columbia, where segregated returns are made for the passenger car and the truck, the latter, while aggregating but 13.14 per cent of the vehicles registered, paid 23.60 per cent of the total taxes collected.

Another and sharp distinction is that between the charge made for a motor truck used as a private carrier and that operating in the

[1] Cf. Motor Registration Fees, Bureau of Public Roads.

common-carrier field. Reference to government reports[1] containing the charges made in twenty-five states shows that the average common-carrier fee is $276.34 as against an average of $64.03 for the private carrier. In addition there is an average franchise fee of $212.31 per common-carrier vehicle. When to both of these charges there is added the average gasoline charge of $105.60, it will be seen that the common-carrier vehicle is today paying a large sum for the privilege of common-carrier operation on the highways.

The gasoline levy is, of course, uniform in amount for all vehicles, since it is levied upon each gallon of gas purchased, but obviously the amount charged against the heavier passenger cars and trucks and busses is much larger than against the smaller and lighter vehicle because of the higher gas consumption per mile of use, and because the average truck and bus mileage is higher than that of the private automobile.

The primary reason for the introduction of the special motor vehicle charge was as a matter of police regulation. As the traffic developed, however, the demand for improved roads grew, and gradually during the past two decades, there has been a striking shift in the source of highway revenue. In part this has been due to a program of expediency on the part of the motorists who have recognized that funds were not always available from general sources to meet their requirements, in part to the fact that there is a special benefit in the form of lowered transportation costs and wider service although that is invariably accompanied by increased land valuations and other and larger general benefits. In 1914 the special motor fees constituted but 5 per cent of the total highway expenditures of the nation.[2] Today they constitute about 70 per cent of the total annual highway bill for all purposes.

When it is remembered that some 30 or 40 per cent of these charges are found in highway bonds which are in turn frequently amortized entirely through the use of motor vehicle fees over a period of years, it becomes evident, as pointed out by T. H. MacDonald,[3] Chief of the United States Bureau of Public Roads, that the amount of special motor vehicle taxes is today largely equivalent to the current taxes required annually by all subdivisions of the government for highway purposes.

[1] Cf. Public Roads, January, 1926, Common-Carrier Truck Fees and Taxes.
[2] Cf. National Tax Assn. Report, page 9.
[3] Facts and Figures, 1926, page 51.

If an analysis is made, however, of the amount of special motor vehicle taxes going directly into the highway funds, it will be found only $476,000,000 of the total are applied directly to that purpose at the present time.[1] Of the remainder but two per cent of the Federal excise taxes of $96,000,000 could be said to go to Federal Highway appropriations although the total is more than the total Federal funds devoted to motor highway purposes.

The personal property taxes, municipal fees, and many other small levies of this character are also diverted into general funds, and to the extent that this is done, economists agree that those who pay these special fees are entitled to credit for contributions whether their use is earmarked or not.[2] The funds devoted directly to highway purposes, however, are sufficient to offset the entire probable maintenance costs and half of the construction costs of all highways in addition.

Tax and highway economists alike divide the road problem into two general classes for tax purposes, those which serve a general motor use and those which are purely local and partake of the character of service facilities for individual homes.[3] If the motor taxes are considered in relation to this division, it will be found that those directly applied to highway use alone are equal to more than the entire cost of construction and maintenance of the main state systems as well as a very large percentage of the secondary roads.

It has been shown that there is a large differential existing between the taxes paid by the private motor truck and the common carrier. In this connection it is perhaps desirable to point out that the common-carrier truck movement of the country constitutes only a negligible amount of the total movement.[4] Whether there were any common-carrier movement or not, the need would still remain for the construction of highways adequate to meet economic private-carrier needs, hence it does not appear that common-carrier requirements have in any way influenced the highway policies. Modern roads would be necessary without these units.

From these statements of fact, it would appear that, generally speaking, the current costs of the highway program are being met almost entirely by the users of the road and no subsidy from any

[1] Facts and Figures, 1927.

[2] National Tax Assn. Report, page 20.

[3] Cf. National Tax Assn. Report, page 10.

[4] Cf. National Tax Assn. Report, page 14.

other form of transportation can be said to exist although these agencies and the general public obtain large correlative benefits from highway development.[1]

It is not doubted that there are specific cases where this statement does not yet apply, but the trend is steadily in the direction of shifting the burden to the motor vehicle, and as long as this does not constitute an undue burden upon the individual, the motorist himself is gradually working to bring about an easement of even these conditions. Meanwhile, the country has obtained an addition to its capital wealth in the form of added facilities the cost of which the Bureau of Census estimates is more than offset by the increased value alone of the land served.

TYPES OF MOTOR VEHICLE TAXATION

General

Federal Income	State Property Taxes
State Income	County Property Taxes
Federal Capital Stock	Municipal Property Taxes
State Capital Stock	

Special

Passenger Cars	*Trucks, Busses, Taxicabs, etc.*
Federal Excise	Registration (state and local)
State Registration	Personal Property
Gasoline	State Franchise
State Driver's License (not for hire)	City Franchise
State Certificates of title	Federal Occupational
City Wheel or Gas Tax	State Gasoline
Personal Property	Driver's License (for hire)
Non-Resident	Garage License
	Gasoline Storage License
	Wheel Tax
	Transportation Tax
	Seating Capacity
	Load Tax
	Lubricating Oil Tax
	Tax on Gross Receipts
	Trailer and Tractor Tax
	Tire Tax (pneumatic or solid)
	City Gas Tax

[1] Testimony J. G. McKay, page 303, Interstate Commerce Committee.

Some of the Different Methods Employed by States in the Collection of Automobile Taxes. Iowa taxes motor busses on a ton-mile basis, obtained by multiplying the seating capacity at 150 pounds per passenger, plus the weight of the vehicle, by the miles operated annually and divided by 2000.

Louisiana taxes the horsepower of the engine in addition to the seating capacity of the vehicle.

Seating capacity per mile of operation is used as the basis for computing the tax in Maryland, Virginia, and West Virginia.

Pennsylvania, New Mexico, Iowa, and Virginia differentiate in their tax rate between vehicles using pneumatic and those with cushion or solid tires.

Seating capacity on a flat rate per seat is used in Alabama, California, Colorado, Connecticut, Florida, Louisiana, Minnesota, New Jersey, New York, North Dakota, Ohio, Tennessee, and the District of Columbia.

The unloaded weight of motor busses is taken into consideration in Maryland, Virginia, Washington, and West Virginia.

Development of the Mechanics of the Motor Car. Contrary to the general belief, patents have had very little direct effect in the development of the automotive industry, and the amount of tribute that the industry has paid to inventors has been remarkably small, because there is very little of value in the way of inventions covered by unexpired patents that the industry has found necessary to utilize. This rather paradoxical situation is due largely to the reason that the patents for the inventions that the industry found necessary to utilize had expired before the industry got into its stride. In other words, the development of the industry has been in the nature of an intelligent selection of ideas that have become public property, and the exercise of sound engineering in combining and coördinating these ideas.

Long prior to the beginning of the industry, the self-propelled vehicle, which comes under the head of railway transportation, had reached a high state of development. Furthermore, beginning over a century ago, road vehicles, self-propelled by steam, have been in existence; and while this development reached no great commercial state, its teachings were available when the automotive industry came into being.

When speaking of the automotive industry we are now referring primarily to the gasoline automobile — or, more correctly, the auto-

mobile propelled by the internal-combustion engine. The development of this industry goes back at least one hundred years. The original developments were naturally quite crude. The first real forwarding step was taken by Otto, when he evolved the Otto Cycle. This was followed by the Daimler-Maybach development, which involved feeding the engine with liquid fuel instead of gas, applying the float-control spray carburetor, the general lightening of the weight, and making the engine more powerful. There were patents on these developments, but they either expired before the American automotive industry got under way, or they were not patented in this country. When the engine had reached this stage of development in the early nineties, the self-propelled gasoline motor vehicle was a foregone conclusion. In all the industrial countries, with the exception of Great Britain, horseless carriages began to appear. Great Britain was out of the picture, due to its ancient law that any self-propelled road vehicle on the public highway must be preceded by a man carrying a red flag. Rumor has it that this law was passed as a result of some influential gentleman having his horse frightened by an old steam stagecoach about 1820.

While these horseless carriages were made and sold, and did move on the highways, they were fundamentally wrong in design for the reason that they took as their basis the horse-drawn carriage, efficient for being pulled by animal power, but totally unsuited for carrying and being driven by the internal combustion engine. In 1894 Panhard and Levassor, in France, brought out a very radical self-propelled vehicle; that is, radical as compared with competing machines. Compared with the cars of today, it had within it every ingredient of correct principle. It had a rectangular chassis frame, a running gear beneath the frame with springs between, the power plant at the forward end, and the passenger-carrier body at the rear. In other words, these three elements, the running gear, the power plant, and the body, did not interfere with each other, so the designer was free to design each one for its needs without conflict with some other portion of the machine.

This vehicle had stub axle steering, and counting front to rear, there was the radiator at the front; next, a vertical engine; next, a cone clutch with details so that it took hold gently first; next, a sliding gear transmission; then a differential on the jack shaft and a sprocket chain drive at the rear wheels. Except for the

now more common propeller shaft, it is the same layout as we have today.

There was a sheet-metal housing for the engine and a dashboard in back of that. The operator had three pedals, and three hand levers for the right hand. The three pedals were clutch, service brake, and accelerator. The three hand levers were gear shift, emergency brake, and a separate lever for reverse. The resemblance of this control to the present-day practice is obvious. Three years later this company brought out the steering wheel type for controlling the direction of the car, having previously used a tiller. The sliding-gear transmission of that car had no direct drive, ignition was not electrical, and the acceleration was effected through control on a centrifugal governor. But the modern principle was there. The jump-spark ignition was available for the internal combustion engine as far back as 1860. The direct drive on the transmission and the propeller shaft instead of the sprocket chain were developed by Renault about 1899, but he did not obtain patents in this country. Strange to say, neither did the Panhard and Levassor Company obtain any patents in this country, at least on the principle of design involved in this Panhard car.

From the time this car came out — 1894 to 1900 — European practice gradually swung over from the old horseless carriage arrangement to this Panhard principle and began to make headway. The manufacturers in this country hung on a year or so longer, but finally fell into line, and likewise began to accelerate for the very obvious reason that they were on the right track and using the right principles of design. From that time on, the development, due to inventions, has been well-nigh universally limited to details which are really minor, and in spite of the flamboyant statement of the advertising and sales departments of the factories, there have been no outstanding patents. Selden, of course, claimed dominance over any gasoline road vehicle, but the courts decided otherwise. Dyer obtained recognition of his patents on transmission for direct drive, which patents were quite widely recognized, but the royalties were moderate. In the majority of cases, they were in lump-sum payment per licensee, which when spread upon the production during the life of the patent, came out to some small fraction of a cent per car. Note also that the car which is produced in the largest quantities never used the Dyer idea. This illustrates

the fact that from the time Panhard developed the correct principles there has not been a detail in any period from then to now, whether subject to the control of a patent or not, that could not have been left off and some alternative substituted with complete satisfaction. The inventions that have been used in this interval were used solely because it was a little more convenient or a little cheaper to pay the royalty than to use the alternative.

Prior to the birth of this industry, there has been available an enormous mass of engineering data in the arts, on machines and details with functions quite analogous to those of the various components of a motor car. So the usual result of an inventor bringing out an improvement on a motor car was to cause the engineer to pause in the grueling race of production and look around for what has been done in analogous situations in the past, with the usual result that he found an equivalent and, in many cases, something better. This was particularly true when the inventor was somewhat exorbitant in his royalty demands. That was merely an added incentive to seek for an alternative. In the few cases where there has been heavy patent litigation directed against car manufacturers, this pausing and looking around has developed alternatives superior to those alleged to be dominated by the patent in question. But it is only a portion of the improvements that are made the subject of patents. To illustrate, the various types of automobile bodies with all their improvements are in a large majority of cases nothing more than a taking of the identical idea from the old horse-drawn carriage art. Many details and improvements on the motor are nothing more than taking the similar idea from steam engines and similar machines; lubrication systems on the motor car have their parallel in lubrication of older machines of all sorts and kinds. The running gear, the wheels, and springs likewise have their parallel in the carriage and wagon art, and some are found to an extent in the railway art. For example, the stub axle steering exactly as it is used today came from Ackerman's work on the stage coaches in 1818.

We do not wish to be understood as in any way belittling the work of the inventor and his effect on the industry. It just so happens that when the general principles of the car were laid down, the details were all to a very large extent already known and available, so there was either nothing to invent or the inventor was necessarily limited, and if the inventor demanded a heavy royalty,

the industry naturally turned to a royalty-free alternative. Of course, engineering work has been of prime importance in developing the industry, but engineering work, no matter how able or brilliant, is something quite separate and apart from invention.

The somewhat minor position of patents in the development of the industry is illustrated by the action of the members of the National Automobile Chamber of Commerce in 1915 in bringing about the Cross-Licensing plan, which is nothing more than a reciprocal exchange of licenses between the members without money consideration, the consideration being the licenses that each member receives in return for those he gives. The fact that this cross-licensing arrangement has functioned smoothly and has prevented patent warfare within the family circle of the Chamber is a demonstration that the inventors have played but a small part in the development of the industry.

Regulation and Legislation Affecting Automobile Industry. Legislation, in the form of regulation, has had a more direct effect upon the operation and use of motor vehicles than it has upon the development of the automobile industry, yet the two are so closely related that a discussion of the one necessarily includes the other.

Motor vehicle legislation has been confined entirely to the state governments, and to date the Federal government has not attempted to enter the field. The only Federal law which relates to motor vehicles at all is that which levies the excise tax for revenue purposes upon the sale of motor vehicles. The earliest laws enacted in America had to do with the regulation of the use of the vehicle, and, as might be expected, these laws were more or less of a restrictive nature. One of the earliest regulations in New York City prohibited motor vehicles from being driven in Central Park, because their operation there would interfere with the horse-drawn vehicle traffic.

Some of these early state laws, when viewed by present-day standards, were extremely ridiculous. An early Iowa law required that motorists should telephone ahead to each village or city giving warning of their intended arrival before starting out on the journey. This law remained on the statute books until some two years ago. Another example of the character of these earlier laws was the Kansas law enacted in 1902, which read as follows:

Nothing in this section shall be construed as in any way preventing, obstructing, impeding, embarrassing, or in any other manner or form infringing on the prerogative of any political chauffeur to run an automobilious bandwagon at any rate he sees fit compatible with the safety of the occupants thereof; provided, however, that not less than ten nor more than twenty ropes be allowed at all times to trail behind this vehicle when in motion, in order to permit those who have been so fortunate as to escape with their political lives an opportunity to be dragged to death; and provided further, that when a mangled and bleeding political corpse implores for mercy, the driver of the vehicle shall, in accordance with the provisions of this bill, "Throw out the life-line!"

Laws relating to the safety of operating motor vehicles were rapidly adopted by the states, and at the present time, every state in the Union has a law placing certain restrictions upon the operation of automobiles under certain conditions, especially regarding speed. These speed limits were at first based upon a low rate of maximum speed. The tendency at the present time has been to increase this maximum rate, due largely to the fact that the matter of speed is no longer considered to be the determining factor in accidents, and, with the rapid growth of improved highways, it has been found necessary to increase the speed limits in order to keep traffic moving to avoid congestion.

While these early laws were not directly aimed at the development of the automobile industry they did, to a certain extent, affect the expansion of the industry because their tendency was to limit the use of the vehicle. However, as automobiles became more common in usage, these laws were amended or repealed until they have become more reasonable in their regulation. The millions of vehicles on the highways at the present time is proof of the fact that laws and regulations have not materially hampered the growth of the automobile industry.

In 1901 the state of New York enacted a law which required the registration of motor vehicles. This example was followed by other states, and by 1914 every state in the Union had a registration law and charged fees for the privilege of this registration. At first these fees were based upon a flat rate per vehicle, sometimes as low as $1.00 per car, and no further registration fee or tax was required as long as the car was in operation. It was not long, however, until the state legislatures began to see an excellent opportunity to increase the states' revenues, particularly for the

purpose of raising money for highways; so, instead of charging a flat rate per vehicle for a permanent license, the registration requirements were changed so that an annual license was required and an annual tax charged for such license. Still later, the basis of the tax was changed from a flat rate to a horsepower or weight basis, or some other method of classification. With the development of hard-surfaced highways a greater amount of money was required to expand the state highway systems, so that new sources of revenue had to be found. This led to the introduction of the gasoline tax, already discussed, which has spread so rapidly during the past eight years in the United States. At the present time all but three of the forty-eight states now have a gasoline tax in addition to the regular registration fees. Motor vehicle taxes have become one of the most important sources of state revenue, and in 1926 the total tax collected from motor vehicles in all of the forty-eight states amounted to more than $700,000,000.

Every state in the Union has laws which place restrictions other than those relating to speed upon the use of motor vehicles. These relate to such things as the size and weight of motor vehicles permitted on the highways. The permissible width ranges from 84 inches to 96 inches, and the weight varies from 15,000 pounds to 28,000 pounds gross weight. The height averages about 12½ feet. The purpose of these restrictions has been to protect the highways from heavy loads and to safeguard traffic generally.

Practically all states have enacted laws requiring certain equipment of vehicles which have now come to be regarded as fundamental requirements. These relate to such things as headlights, brakes, horns and other signals, rear-view mirrors, and muffler cut-outs. None of these regulations, however, has materially affected the design and construction of the vehicle, and the manufacturers have been left free to work out this phase along sound engineering lines.

All states have enacted more or less complicated sets of rules for driving, commonly called "Rules of the Road." These rules provide that all vehicles shall be operated in a certain manner under certain conditions. These regulations have not been uniform throughout the states, and a great deal of confusion has resulted when motorists have gone from one state into another. However, there is now a decided tendency toward uniformity and

it will be only a matter of a few years until the rules in all the states will be practically the same.

One of the more or less recent developments in motor vehicle regulation has grown out of the rapid development of the use of busses and trucks for the transportation of persons and property for hire. Such vehicles have, because of the nature of their business, been classified and regulated as common carriers. Pennsylvania, in 1914, was the first state to place the regulation of the business of operating passenger and property carriers for hire under the jurisdiction of the Public Service Commission. This movement has spread until forty-four states have passed similar laws regulating passenger carriers, and some thirty-three states have laws regulating property carriers. These laws generally require the procurement of Certificates of Convenience and Necessity before operation is permitted, and places the general regulation of rates, fares, charges, and operation under the jurisdiction of the Commission.

While, in certain instances, it can be said that some of the laws and regulations have been too stringent, on the whole, however, they have been reasonable in character and have not interfered with the rapid development and expansion of the manufacture of motor vehicles and their use.

Maintenance a Factor in the Automobile Industry. The automobile industry, in common with a few other industries but unlike most, is not through with its product after it has been sold. Interest in the performance of motor vehicles must be maintained by the manufacturers as long as they remain in operation. So, added to the two great divisions common in all manufacture — production and sales — the automobile industry has service or maintenance. This requires that the factories shall have service and parts departments and the distributing outlets shall have repair shops to afford owners the means for keeping their transportation equipment in operating condition. However well built, motor vehicles require repairs and adjustments sooner or later; sooner, as the result of accident, abuse, or misuse, and later from normal wear.

It is the function of the factory service departments to assist the distributors and dealers and their service personnel on best methods of repair, efficient shop layouts, tools and equipment, systems for the handling of work, stocking of parts, accounting,

customer treatment, etc., etc., to handle the maintenance business with satisfaction to all concerned. Of first consideration is the customer who should be able to get good work, quickly done at reasonable charges. Next comes the retailer who should be able to do good work promptly and reasonably, but at a cost that leaves him a fair profit. And finally satisfactory maintenance for the car owner is vital to the factory in the interest of further sales of new cars to present owners and their friends. Assistance given by the factory service departments is in the nature of advice, suggestions, or instructions.

Usually operated as a division of the service department, though sometimes independently, is the parts department, the function of which is to supply the distributing outlets with replacement parts and advise them how to regulate their stocks according to the probable frequency of demand so that there may be a minimum of occasions where repairs are delayed awaiting shipment of parts from the factory. The comparative youth of the automotive industry and its phenomenally rapid expansion have made the evolution of its service factor unique. There was little to guide it from the experience of other industries, for its problems were highly specialized, of larger proportions, and in most regards radically different from those encountered in servicing older mechanical products.

In very little more than a quarter of a century the maintenance business alone has grown from nothing to a volume measured in dollars expended annually of nearly two billion for parts and labor. At this writing there are registered in the United States over 22,000,000 motor vehicles, to care for which there are nearly 86,000 repair shops, including both dealer service stations and independent shops, employing all told in the neighborhood of 436,000 people.

It is quite in the natural order of events that the service element of the industry has been the tardiest in its development. In fact it may be considered the fourth and last stage. First in any industry is the experimental stage. Then when a reasonably reliable product has been evolved comes the production stage. When production exceeds demand the merchandizing factor becomes predominant and finally service takes its place as an equally great essential. Of course, all four stages overlap, for all four elements have been involved from the beginning and will continue to be.

The division into periods merely marks the time while each of the four elements drew the greatest share of attention and effort and underwent the largest development. In this sense the industry is at present in the fourth stage and an interesting transition is taking place. During the first three stages service was performed as a matter of necessity to minimize its resistance to new-car sales. Being poorly organized, it was so expensive that no hope for profit from that department could be entertained. The dealer's object was to keep his service losses from wiping out his profit from selling new cars. In other words service was a by-product of new-car sales.

Meantime there was growing the complication of the used-car problem. To sell new cars to prospects already owning cars competition compelled taking old cars in trade, usually at excessive allowances, so that the used cars were resold at a loss, and here was a further inroad into the dealers new-car sales profit. It took a considerable dealer mortality to teach the lesson that all departments of the dealer's business should not only be self-supporting but revenue producing. Realizing that charges for repairs could not be increased, the only solution was to reduce the costs, and studies to that end both by factories and dealers were fruitful.

Better equipment, better trained men, better system all contributed to lowering the costs for rendering service until today the outstandingly successful dealers are those who are realizing as much or a greater profit from their service department than from their sales. They have not only not increased charges to customers but have decreased them and thus invited a still greater volume of business and thereby reduced their overhead.

Given a volume of work that justifies investment in special equipment and processes there can then be applied to the maintenance branch of the industry the same principles that have made possible the production and sale of new cars at the remarkably low prices, quality considered, that now prevail. As compared with 1914 the automobile dollar is now worth $1.13, while the cost-of-living dollar is worth only 60 cents.

This awakening of " service consciousness " came at about the same time that there was borne in on the industry the realization that it is selling not motor vehicles but motor transportation, that building of cars is not half of the business. In 1926 the nation's expenditure for new cars and trucks was about four billion dollars

and its total operation and maintenance expense, exclusive of depreciation and garaging, was nearly five billion dollars.

There is fascinating play for the imagination in visioning the future for the maintenance field of this industry when engineering and scientific management have accomplished anything comparable with what they have already done in the field of manufacture and when as high a standard of salesmanship as is now evidenced in the distribution of cars prevails in the sale of service.

CHAPTER III

BANKING IN THE UNITED STATES

By H. Parker Willis [1]

The history and present position of banking in the United States mark the occupation as different both in its form and methods from the banking systems of other countries. In some ways, the American type of development has been of such a nature that banking may be properly described as an "industry"; for nowhere has the technique of bank creation, bank amalgamation and merging, and, it is to be admitted, bank failure, been as highly developed as in the United States. Nowhere else, it may be added, is there the same closeness of general relationship between banking and business, as generally exists in the United States, although it is perfectly true that in many countries there is much better banking organization and a much more clearly defined affiliation or interrelationship between banking and commercial institutions. American industry has been built upon a structure of credit, and it looks constantly to the bank as a means of promoting and vivifying business. It uses credit as perhaps no other nation uses it, and the study of credit from the American standpoint is in many ways essentially a study of American business.

Structure of American Banking. In getting a clear conception of the industrial position of American banking at the present time, it is well to sketch briefly the general structural outline of our banking system. It is a system which had been developed without any coördinating plan until it reached maturity, connecting links designed to unite the different parts being subsequently built into it. The result is to produce a piece of financial architecture which in some ways is strong and serviceable, but quite obviously possesses the defects that are inherent in its peculiar origin and later growth.

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The oldest units in the present system of American banking are of course the so-called "state banks," which in the older states date from a period not long after the Revolutionary War, while in the newer states they date almost from the earliest periods of organized settlement. Thus we have in practically all of the forty-eight states local state systems of banking law, which differ more or less from one another in detail, but which possess the same general underlying characteristics. In each state, the banking law makes provision for the organization of new banks by a specified minimum number of persons who must raise a specified minimum capital, usually from $15,000 to $25,000, make application to a state official, variously called commissioner of banking or state superintendent of banks, receive from him a charter, and thereafter open and operate a bank in accordance with the rules laid down in the law for the management of the institution in question.[1] By the side of these forty-eight systems of banking, there have grown up in every state so-called national banks, chartered by the Federal Government under the National Bank Act, which dates from 1863, although many times amended since that date. Under the National Bank Act the specified minimum number of persons make application to a Federal official called the Comptroller of the Currency, obtain from him a charter upon the basis of a capitalization never less than $25,000 and increasing in proportion to the size of the place in which the bank is located, then carry on the business in accordance with the general provisions and requirements of the National Bank Act itself.

The Federal Reserve Banks are banks chartered in each of 12 districts into which the country as a whole has been divided, their stock being compulsorily owned by the several member banks in each district in proportion to size. Overseeing these banks and presumably acting as a central board of directors is a body known as the Federal Reserve Board, with headquarters at Washington. The board may permit banks chartered under the laws of the several states to become members of reserve banks on equal terms with national banks, in which case they of course take out, pay for, and own stock in such federal reserve banks upon the same terms and conditions which prevail in the case of national banks, while these state banks are themselves at liberty to withdraw from

[1] Trust companies are likewise organized under state charter, see page 120, *infra*.

membership in the federal reserve banks of their districts whenever they please, on giving due notice and complying with certain reasonable specifications.

It would not be sufficient to outline the commercial side of American banking without at the same time sketching briefly the structure which has been developed for dealing with land credit. This consists of 12 federal farm loan banks located in districts not exactly identical with, but roughly corresponding to, the 12 federal reserve districts, and of about 57 joint stock land banks situated wherever the incorporators choose to place them. Along with these institutions should also be mentioned 12 intermediate credit banks which are in a certain sense departments of the federal farm loan banks, having the same boards of directors and the same general management besides being like them responsible to a Farm Loan Board at Washington. The Federal Farm Loan banks are coöperatively owned by farm loan associations, which associations, numbering about 3500, are local groups of farmers organized for the purpose of borrowing. Joint stock land banks are owned by individuals who subscribe for, or buy, their stock just as they would the stock of any other corporation.

With this brief sketch of the structure or organization of banking in the United States, it is now possible to describe in broad general terms the financial structure of the borrowing public; — the conditions under which borrowers deal with banks, and the banks with which given classes of borrowers find it expedient or desirable to hold financial relations and to carry on business operations. This involves an outline of the clientele which is served by each of the groups of financial institutions whose existence has been depicted in the foregoing paragraphs.

Fundamental Type of Borrowing. The fundamental type of borrowing in the United States is the direct single-name note, made by the individual or corporate borrower and signed by the individual himself, or by the officer of the corporation on whose behalf the borrowing is done. In the latter case, of course, the necessary authority must be granted by the corporate board of directors and filed with the bank from which the loan is sought. Single-name notes of this kind represent the extent to which the bank is willing to go in advancing funds upon the basis of the borrower's unsupported credit. In order to do business with the bank on this basis, it is of course necessary to supply it with infor-

mation as regards the general condition of the borrower who is making application to it, and this information gives rise to what is called a " line of credit." Such a line of credit represents the extent or scope of the aggregate borrowings which the bank in question is willing to grant upon the demonstration of a certain state of business on the part of the borrower. The extension of such a line of credit is necessarily the result of careful analysis of the position of the enterprise, and this study may take form as an analysis of the statement furnished by the borrower and in many cases prepared or approved by an accountant of standing. Where the loan is considerable in amount, such a statement will be necessarily backed up by further details as to the condition of the business, the valuation of its assets, its past record as a borrower, and a variety of other factors. In some cases, it may also be essential to obtain a similar analysis of the condition of the individual directors of the corporation, or if the borrower be an individual, similar statements concerning the financial position of his wife or of other members of his family or of his partners. When the credit data has been assembled and careful scrutiny given to the condition and requirements of the business itself and of the branch of business to which it belongs, the bank determines the total amount of loans which can be granted, and then the action of the borrower in obtaining advances up to this maximum amount upon ordinary single-name paper is merely a matter of routine administration.

Effort has been made for some years past to introduce the use of two-name paper by popularizing the so-called trade acceptance. In using this instrument the seller of goods draws on the buyer, the paper then being accepted by the latter, and so becoming bankable with the protection not only of the concern which actually presents it for discount, but also with the contingent liability of the other whose name appears upon the face. This effort has not been very successful, a major reason being that in America business is not organized upon the same footing as in foreign countries. The introduction of the practice of granting trade discounts has made it possible for the buyer of goods to choose any one of two or three bases upon which he will settle, according to whether he requires more or less time in which to liquidate his obligations. At the same time, the fact that he has this choice prevents the seller of goods from knowing on which basis he will settle and hence makes the use of a trade acceptance difficult or in some cases impossible

since it must, like other negotiable instruments, be drawn for "a sum certain." It is also to be remembered that the shift from the single-name paper basis to the trade acceptance presupposes the possibility of having a similar credit foundation. But, as a matter of fact, the trade acceptance or two-name paper is founded upon an entirely different theory of credit — that, namely, which prefers the knowledge that actual goods have been received and that a given discount is intended to provide the means for settling a certain invoice, to the more intimate knowledge of internal conditions which is furnished by a financial statement. It is not practicable to shift from one basis to the other, although there is no reason why a bank should not discount for its customers upon either plan if consistently used. However, as already stated, the practice of American business is against the use of the trade acceptance, and it has never been easy to introduce it into general use.

Collateral notes present a different situation. It is the practice of many concerns which expect to borrow upon single-name paper but which do not care to furnish a detailed financial statement, to get accommodation upon the basis of collateral security which they carry for that purpose. In some cases the collateral loans so placed may be additional or supplementary to the loans obtained on statement, or vice versa. Collateral notes are also the prevailing usage with concerns which are borrowing the money for the purpose of trading in securities. The securities so used become the protection for the loan, and as long as they enjoy a wide market protect the bank fully, provided it is carefully scrutinizing the movement of quotations. Within recent years the collateral loan idea has been applied in many new fields and with increasing success. The Federal warehouse law has paved the way for the issuance of uniform warehouse certificates, and the result has been to bring about the use of standard requirements. Observance of these has practically made the warehouse certificate a negotiable instrument which, when issued against staple commodities of known value, furnishes the safest type of loan, provided that the banker does not allow himself to become overburdened with too large a volume of any one kind of security.

In foreign trade it is true that American banking, like the banking of other countries, has developed a special technique. It is also true that this special technique of foreign trade lending has been improved and added to in American practice, in such a way

as to adapt it more fully to the requirements of business in the United States. Fundamental in such foreign trade finance is of course the bill of exchange or draft, either documented or clean, the documents in the former type of paper being the same as those that are universally required in such transactions, and including bills of lading, insurance policies, suitable consular and other papers, and additional certificates when required by the law or custom of specified countries with which the trade is being carried on. The bankers' acceptance was not used in the United States prior to the adoption of the Reserve Act, but has gained some ground in the thirteen years that have passed since the Act went into effect. Today a number of bankers are accepting drafts drawn on them in behalf of clients both in importation and exportation, while they are also accepting a good deal of similar paper in domestic trade. Most of the foreign acceptances are documented, while a large share of the domestic issue is protected only by warehouse receipts indicating goods in storage or by some other type of security, and is thus really a special form of secured loan. The letters of credit providing the terms under which drafts may be drawn have become more and more a favorite mode of regularizing banking business, and both export and import letters are now freely employed by most of the large banks engaged in financing foreign trade. These letters are of the same general descriptions as are employed abroad, although, as already stated, modifications both in tenor and usage have been made in order to adapt them more fully to American requirements. It cannot, however, be said in all cases that such modifications have been beneficial or helpful in making the letters more desirable as a basis for drawings.

It is worth while to sketch briefly the relative proportions in which the different types of paper make their appearance in American banks, and for that purpose the following tables have been selected from the last report (1926) of the Comptroller of the Currency with a view to giving a representative sketch of the comparative amounts of business of the different classes that are done by American institutions. The figures relate to national banks only but are substantially characteristic of the entire banking situation.

The table following discloses, by reserve cities and states, a classification of miscellaneous securities held by national banks, together with a total of United States Government securities, in the years ended June 30, 1925 and 1926:

CLASSIFICATION OF LOANS AND DISCOUNTS FOR THE LAST THREE FISCAL YEARS

[In thousands of dollars]

Class	June 30, 1924		June 30, 1925		June 30, 1926	
	Amount	Per Cent	Amount	Per Cent	Amount	Per Cent
On demand, paper with one or more individual or firm names (not secured by collateral)	737,559	6.16	726,100	5.73	775,107	5.78
On demand, secured by stocks and bonds	1,545,625	12.90	1,843,167	14.54	2,053,871	15.31
On demand, secured by other personal securities, including merchandise, warehouse receipts, etc.	263,618	2.20	300,561	2.37	324,405	2.42
On time, paper with one or more individual or firm names (not secured by collateral)	6,123,604	51.12	6,132,318	48.39	6,344,135	47.28
On time, secured by stocks and bonds	1,559,698	13.02	1,817,730	14.34	1,982,754	14.78
On time, secured by other personal securities, including merchandise, warehouse receipts, etc.	1,087,096	9.08	1,062,755	8.39	1,133,621	8.45
Secured by improved real estate under authority of sec. 24, Federal reserve act, as amended:						
1. On farm land	116,009	.97	122,214	.96	123,641	.92
2. On other real estate	188,897	1.58	269,247	2.12	337,393	2.51
Secured by real-estate mortgages or other liens on realty not in accordance with sec. 24, Federal reserve act, as amended:						
1. For debts previously contracted (sec. 5137, R. S. U. S.) —						
(a) Farm lands	120,122	1.00	123,332	.97	116,887	.87
(b) Other real estate	74,535	.62	81,874	.65	92,605	.69
2. All other real-estate loans —						
(a) Farm lands	9,031	.08	10,334	.08	11,555	.09
(b) Other real estate	26,543	.22	29,797	.24	43,371	.32
Acceptances of other banks discounted	91,026	.76	107,767	.85	78,329	.58
Acceptances of reporting banks purchased or discounted	33,998	.28	43,766	.35	(1)	(1)
Customers' liability on account of drafts paid under letters of credit	1,367	.01	3,105	.02	(1)	(1)
Total	11,978,728	100.00	12,674,067	100.00	13,417,674	100.00

[1] Not called for on June 30, 1926.

[In thousands of dollars]

	June 30, 1925	June 30, 1926
Domestic securities:		
State, county, or other municipal bonds	594,700	647,801
Railroad bonds	673,950	631,387
Other public-service corporation bonds	495,239	545,036
All other bonds	698,235	772,789
Claims, warrants, judgments, etc.	90,548	79,423
Collateral trust and other corporation notes	124,828	154,797
Foreign government bonds	240,762	225,871
Other foreign bonds and securities	122,163	146,548
Stock, Federal reserve banks	74,488	78,735
Stocks, all other	78,764	90,598
Total	3,193,677	3,372,985
United States Government securities	2,536,767	2,469,268
Total bonds of all classes	5,730,444	5,842,253

[In thousands of dollars]

	June 30, 1922	June 30, 1923	Per Cent Increase (+) or Decrease (−) since June 30, 1922	June 30, 1924	Percent Increase (+) or Decrease (−) since June 30, 1923	June 30, 1925	Per Cent Increase (+) or Decrease (−) since June 30, 1924	June 30, 1926	Per Cent Increase (+) or Decrease (−) since June 30, 1925
Demand deposits	9,152,415	9,288,298	+ 1.48	9,593,250	+ 3.28	10,430,254	+ 8.72	10,778,603	+ 3.34
Time deposits	4,111,951	4,755,162	+ 15.64	5,259,933	+ 10.62	5,924,658	+ 12.64	6,313,809	+ 6.57
Loans and discounts [1]	11,248,214	11,817,671	+ 5.06	11,978,728	+ 1.36	12,674,067	+ 5.80	13,417,674	+ 5.87
United States and other bonds, stocks, etc.	4,563,325	5,069,703	+ 11.10	5,142,328	+ 1.43	5,730,444	+ 11.44	5,842,253	+ 1.95
Lawful reserve with Federal reserve banks	1,151,605	1,142,736	−.77	1,198,670	+ 4.89	1,326,864	+ 10.69	1,381,171	+ 4.09

[1] Includes rediscounts and customers' liability under letters of credit.

The percentage of increase or reduction of each of the resource and liability items referred to since June 30, 1922, is shown in the table on the previous page.

A brief description of the kind of business which comes to federal reserve banks is also necessary by way of supplementing what has already been said of the general structure of the borrowing community with which the various commercial banks have to deal. The reserve banks, although authorized to deal with the public at large under certain specified conditions (not involving the carrying of deposits) have never done so save through the purchase of open market paper, — largerly acceptances. The bulk of their business has been carried on through direct rediscounting on behalf of the other banks who are members of the system, *i.e.*, who hold stock in federal reserve banks.

This rediscounting is presumably limited to short-term commercial paper (not over 90 days) growing out of business or industry; or agricultural paper (not over 180 days) of a satisfactorily liquid sort. The notes presented are required to be in standardized form, and when above a figure of $5000, must be accompanied by a statement of the condition of the borrower, for the purpose of rendering possible a complete analysis of his position. Federal reserve banks thus presumably rediscount for their members liquid paper which the latter have received from their customers as the outgrowth of short-term operations of a legitimate variety and business or agricultural industry. The types of operations which are forbidden under the Federal Reserve Act include all those of a speculative variety, yet this has not prevented the Federal Reserve Board from authorizing the discounting of paper protected by warehouse receipts and representing commodities in storage, especially agricultural commodities. Amendments to the Federal Reserve Act have also authorized the making of direct loans to banks on their own notes if protected or collateraled by an equal quantity of eligible paper which might otherwise have been rediscounted. The business of federal reserve banks may thus include customers' notes with bankers' endorsement and bankers' own direct notes collateraled in various ways.

Banking and Industry. The relationship between banking and industry in the United States is not the same as that which prevails in some of the continental countries. Originally the American conception of the bank was undoubtedly copied from that of Great

Britain and was based upon the idea that banking should be an independent occupation or profession whose purpose it was to deal with all kinds of business enterprises, to receive from them applications for loans, and to pass upon such loans in proportion to their ability to liquidate, bearing in mind, of course, the other factors of availability, profitableness, and the like, which affect the eligibility of offerings. In this view of the case it was logical, of course, that the directorate of a bank, although usually made up of business men, should consist primarily of persons who were not likely to borrow heavily from the bank or to be identified with enterprises which were likely to be exceptionally heavy borrowers. We still have a tradition of this sort in most of our banking institutions, and it is frequently held by examiners that excessive loans to the directors and officers are "unethical," while examiners usually insist upon having all loans to directors carefully listed as if they were subject to some special kind of scrutiny or control. These may be regarded as survivals of an older idea of banking. They are inconsistent with the practice of American banks at the present time in endeavoring to obtain on boards of directors men who are large property owners or in position to turn business toward the bank, or otherwise to advance its interests. In fact, newly organized banks at the present time almost necessarily take pains to obtain as members of their boards at least a fair proportion of men who are in position to bring in business. When once a bank is organized, directors are expected to exert their influence in attracting deposits, and since, under our practice, deposits are the outgrowth of loans, the process of getting deposits inevitably brings with it the granting of lines of credit and the making of loans accordingly.

All this is quite in line with the tendency of banking development in Germany and other continental countries where banks, instead of being organized on a "horizontal" plan, doing business with many persons and enterprises in all branches of business, are primarily developed upon the so-called "vertical" basis, seeking to develop as well as they can the business of a particular branch of industry, and doing their utmost to cultivate the support and recognition of concerns in that kind of business. In return for such support they undertake to finance the industry in question, while at the same time they are governed by directors who are important factors in businesses of the kind referred to. No doubt

the tendency in the United States may be said to be toward a modified form of the German plan of bank organization in so far as relates to industry. This tendency is exemplified in the fact that a good many American banks are now quite frankly devoted chiefly to caring for the wants of different types of business, such as the textile trade, the metal trades, stock exchange operations, and the like. One factor which has undoubtedly tended to drive bank organization in this direction has been the circumstance that, with some 28,000 banks in existence, it would be very difficult to obtain boards of directors who were not themselves directly interested in borrowing from the bank.

Be the cause what it may, the fact remains that at the present time the ordinary bank, especially if of new or recent organization, desires to establish a close relationship with business enterprises by granting to them representation on its board; and while we have yet to develop a full measure of classification of banks which would result in assigning given institutions definitely to specified types of business and vice versa, it is also true that the movement in that direction is quite well advanced.

It may thus be said that an increasingly close interdependence between banking and industry has been developed in the United States, and that in the case of a new or growing industry the effort of those engaged is to bring about the organization of banks which they either control or at least are able to direct in some considerable degree. This situation undoubtedly lays a very large burden of responsibility upon the banker, since it subjects him to the constant temptation to become unduly subservient to given enterprises; or if not that, to become entangled with given lines of industry, with the result that he tends to share the same ups and downs of prosperity and depression to which they are subject.

Influence on Federal Reserve System. The movement just referred to was already in active progress a good while before the formation of the Federal Reserve System and it would be quite unfair to say that present tendencies are thus the outcome of the creation of that system. Nevertheless it must be admitted that the organization of the Reserve System has had its effect in hastening or promoting developments of the type described. This influence has been exerted somewhat as follows: prior to the organization of the system, banks throughout the country, and particularly the smaller banks, felt it essentially necessary that they keep a

substantial percentage of their funds in what was called liquid form. This usually implied the investing of their funds either in paper produced by enterprises outside their own immediate area or else the depositing of cash with banks in other parts of the country, a practice which often led to a corresponding amount of investment in stock market loans. Whatever may have been the defects of this system — and they were serious — they at least had the effect of spreading out the investments of banks over larger areas of industry and of putting their funds into many different kinds of paper. The consequence was to set up a rather vigorous influence working away from undue concentration in particular lines, thus preventing highly localized and special industries from absorbing too much of the resources of given banks. In these circumstances the working out of interbank arrangements produced a kind of rough diversification of portfolio. When the Federal Reserve System was established, its efforts were for some time naturally and inevitably concentrated upon the financing of the War, and it was not until after the War was well over that its full influence upon general banking conditions became felt. When this influence did thus make itself apparent, it took form first of all in producing a rather undue feeling of assurance on the part of many bankers that they would be " taken care of " in the event of trouble, and this feeling of assurance led them in many cases to the development of a rather unliquid portfolio, containing merely one element of paper which was believed to be " eligible," or in other words available, as a means of obtaining funds at reserve banks in case of necessity. The unfortunate tendency which was thus produced was intensified during the so-called prosperous years after 1921 by the fact that a great many business enterprises paid off their bank obligations and provided themselves with working capital by issuing bonds or notes thus eliminating themselves as makers of short-term paper, at least to the same considerable extent in which they had formerly supplied it. These concerns, moreover, appearing now as makers of bonds and notes, naturally found their banks disposed, as the result of knowledge of their business and as a matter of habit, to purchase such obligations with spare funds because of their knowledge of the position of their old customers. Thus a tendency to the substitution of long-term obligations for short-term became more and more marked. The result was described by the Federal Reserve Board in its Annual Report

published in March, 1927, in which it set forth the change that has come over banking portfolios during recent years as follows:

"This increased use of bank funds in longer term enterprises, which has continued for a number of years, has been particularly pronounced in the recent five-year period of growth of bank credit beginning in the spring of 1922. The following table shows the composition of the earning assets of reporting member banks in leading cities in the spring of 1922 and at the end of 1926:

MEMBER BANKS IN LEADING CITIES

[In millions of dollars]

	Total Loans and Investments	Loans on Securities	All Other Loans	Investments	Per Cent of Total			
					Loans on Securities	All Other Loans	Investments	Loans on Securities plus Investments
Mar. 8, 1922	14,527	3,530	7,366	3,631	24.3	50.7	25.0	49.3
Dec. 29, 1926	20,110	5,852	8,717	5,541	29.1	43.3	27.6	56.7
Percentage of increase	38.4	65.8	18.3	52.8				

"During this period of nearly five years, the proportion of loans and investments of member banks in leading cities that was in securities and in loans on securities increased from 49 to 57 per cent. The largest growth, both absolutely and relatively, was in security loans, which increased by about 66 per cent during the period. That this growth in loans on securities represents to a considerable extent an increased volume of credit used in financing transactions in securities at the New York Stock Exchange is indicated by the rapid growth during the period of loans to brokers and dealers in securities in the New York market. Security loans other than brokers' loans in the New York market have also increased, however, and the increase in these other collateral loans represents to some extent the result of a growing practice among commercial and industrial borrowers of obtaining accommodation at their banks for current requirements by means of loans secured by stocks or bonds. While no statistics of the volume of this class of loans are available, there is evidence indicating that the practice is not uncommon, and that at least a part of the growth in security

loans has represented commercial loans, with securities as collateral. All other loans, as reported by the member banks in leading cities, showed a much slower rate of growth during the five-year period than did security loans, the percentage of increase being 18 per cent, compared with 66 per cent for security loans; and while the proportion of total loans and investments of the reporting member banks in security loans increased from 24 per cent in 1922 to 29 per cent in 1926, the proportion in all other loans declined from 51 per cent to 43 per cent during the period."

Obviously the tendencies which are thus set forth by the Reserve Board in the citation just quoted represent a tendency to unite our banks still more closely with industrial enterprises, and this tendency may be expected to become more and more pronounced in the future.

Dangers of Failure. It would be going too far to assert that the increasing intimacy of relationship between American banking and industry has already resulted in serious weakness of the banking structure, and yet the existence of such weakness must be recognized, as well as the fact that in many cases at least it is due to an overdependence upon the business of a particular industry. In noting this tendency it is appropriate to call attention to the great number of failures in our banking system and to sketch briefly the causes which have been at work to bring them about. The following table furnishes the compiled data as to failures and failed assets for the United States for a period of three years, and from this it will be seen, in comparison with earlier figures, how greatly the tendency to failure has intensified itself. Since 1920, total failures now aggregate well toward 5000 in number.

BANK SUSPENSIONS, 1924 TO 1926

Class of Bank	Number			Deposits (In Thousands of Dollars)		
	1926	1925	1924	1926	1925	1924
All banks . .	956	612	777	284,287	172,900	213,444
Non-member banks	796	466	618	214,422	105,636	138,975
Member banks — total	160	146	159	69,865	67,264	74,469
National . . .	125	118	122	48,919	58,537	60,889
State	35	28	37	20,946	8,727	13,580

The causes of this failure epidemic are naturally complex and it is always unwise to endeavor to assign specific reasons for a large general movement. The bulk of failures in number, however, have been found in agricultural states and regions and are evidently due to the fact that the banks there had embarked too great a proportion of their funds in local enterprises, notably agriculture and businesses associated with it. This policy had become rooted during the War and the inflation which persisted for some time after the War, but the point which is of interest in this study is the fact that it represents the outgrowth of an undue dependence of a particular kind of industry upon banking. The situation thus indicated is not, however, confined to agriculture, but has been noted in connection with a number of types of enterprise. Whatever may be accepted as the cause of it, it shows the existence of a generally weak position and one which must be corrected if American banking is to retain a serviceable status.

Branch Banking. Closely in conjunction with the question of bank failures should be considered the general problem of branch banking, and in studying this matter, a brief background sketch must be given of certain tendencies which have made themselves apparent in the banking systems of foreign countries. During the past 25 years, two drifts or trends have been very notable in practically all of the foreign countries: the one, a steady decline in the number of separately organized banks; the other, a great expansion in the number of branches. On the whole the tendency of banking in most countries may be said to have been of recent years toward a reduction in the number of institutions and of increase of the number of offices. As the result, the technique of management of branch banks has been developed into a well-understood branch of the science of management, and most institutions which are allowed to develop along branch lines have exerted themselves to extend their business through that means. As a result, of course, the single-unit lending capacity of most foreign banks has been immensely expanded and their capacity to withdraw funds from one part of the country where at the time they are not being used and to shift them to another has been greatly enlarged, thus adding to the flexibility of such a banking system. In other ways, too, the branch banking method has approved itself, as is shown by the fact that in few if any countries outside of the United States has there been serious resistance to its forward

movement. In the United States, however, opposition to branch banking has been of long standing. The early free banking movement which developed in this country, the fact that bank charters were granted in great numbers under the separate state jurisdictions, and the isolated character of many portions of the United States, combined to strengthen the opinion that liberty of action in establishing banks was essential to financial independence. The widespread popular prejudice against, and fear of, "trusts" tended strongly to strengthen this attitude of mind, and the result was a rapid development of an independent banking system composed of many thousands of independent units, among which a few assumed large size, growing with the cities in which they were located. Of recent years, however, a movement toward the introduction of branches has become much more widespread and as a result some seventeen states have directly granted permission for the establishment of branches by banks existing within their limits. National banks have never been granted the branch privilege, and although for some years prior to 1927 complaisance on the part of the Comptroller of the Currency permitted the opening of certain "offices" which were really branches, it was not until the latter year that, through the passage of the McFadden Act, national banks were given a limited right to establish branches in their own city. Up to 1926 the position of branch banking in the United States may be described substantially as follows:

1. Branch banking authorized by law or regulation in 19 states and the District of Columbia and by a limited number of states within city limits.
2. Total number of states in which branches exist, 31.
3. Total number of branches in the United States about 2777, of which about 2350 are branches of state banks.
4. National banks are operating branches in 22 states.

Branch banking has thus taken a deep root even in the somewhat unfriendly soil afforded by American legislation, and one reason why it has done so is doubtless found in the increasing demands of industry. For a long time business has had the tendency to grow in unit size considerably faster than did American banking.

Investment *Versus* Commercial Banking. No review of American banking would be complete without an explanation of the relationship which exists between commercial and investment banking in the United States. The organization of the capital

market and its status as regards connection with the short-term money market is quite different in the United States from that which has been developed in any of the other highly capitalistic countries. Starting with the British idea of banking as essentially a short-term paper type of operation whose managers were expected to divorce themselves so far as might be from long-term transactions or from speculative operations, American banking very early found itself compelled to compromise sharply with its principles. In the newer states it soon appeared that local borrowers could not develop a local capital market, since these states were in need of new capital for developmental purposes, yet were hardly in position to draw it by the ordinary methods of borrowing from the older markets of the East. All through the agricultural West, therefore, it early became the practice to borrow from the bank for agricultural and business development, nominally on comparatively short terms, but really with the understanding that indefinite renewals would be granted. The small banks all over the country thus became in reality a combination of commercial and investment banks, notwithstanding that their transactions were almost wholly carried on their books as "loans." In the eastern states and in the larger cities throughout the country, the steady growth of corporate enterprise soon developed the need for a different type of banking organization, and from this necessity sprang the so-called trust companies of the early nineties which represented the composite outgrowth of a need for fiduciary service and for investment banking. These trust companies early took on many of the functions of stock and bond issue and management along with their purely fiduciary duties, and in so doing they became investment banks of a new type, not exactly corresponding to anything in European practice. The character of their business in this regard can be better understood when it is remembered that even at the present day they number only about 2500 among the 28,000 banks of the country and are confined largely to the cities.

Private banks or banking firms are of long standing and were for a long time usually ordinary partnerships whose members devoted themselves to financing transactions and the flotation of new issues. The more recent tendency has been in the direction of corporate organization for such enterprises, but the older partnerships both in New York and in other parts of the country, although not very numerous, successfully maintain themselves.

Both they and the incorporated financing firms, sometimes referred to as bond houses and sometimes as investment banks, devote themselves definitely to the work of obtaining and providing capital for business enterprises, furnishing the means for the expansion and enlargement of plants, public utilities, and other undertakings and conducting refinancing or refunding operations whenever necessary. In carrying out this function, such partnerships and houses necessarily have to rely upon the banks and trust companies for the actual capital which they need, soliciting the aid of such financial institutions not only in securing a wider distribution of the securities which they are offering, but also in temporarily "carrying" those portions of the issues which remain unsold for the time being. The method thus adopted is obviously very different in its effect from that which is pursued in those countries where industrial and commercial banking are carried on together, as, for example, in many of the German banks. It has often been questioned, of course, whether such banking organization was on the whole preferable, inasmuch as the reliance of these financial firms and houses upon the banks, and the use of the latter's funds in distributing and carrying the new securities doubtless "ties up" the funds of the latter or puts them into partially "frozen" form, to about as great an extent as would be the case in any event. This doubt has taken tangible form in the adoption of the amendment to the National Bank Act passed by Congress in 1927, wherein provision is made for permitting the banks organized under the national act to engage in the business of buying and selling investment securities. Since the banks had already been permitted under the Federal Reserve Act to engage in fiduciary operations, and since these fiduciary operations had also in many states been copied by local institutions acting under authority granted by state legislatures, the American banking system is fairly in a way to evolve a type of banking in which investment and commercial operations are departmentalized and are then conducted under the same management, indeed under the same roof. A complete change of this kind will, of course, come slowly, and in the meanwhile the original spirit of American banking continues opposed to the apparent or admitted fusion of commercial operations with those of an investment character, even though the nominal separation of them be technical rather than real. For a good while to come, it must be expected that the ground already gained by the

older organization of American banking on the investment side will not be lost, and that whatever is done under the newer provisions of law will be slowly built up, so that the alteration of fundamental structure will continue more or less gradually. At present, it remains certainly true that a business enterprise which desires to recapitalize itself or to place new securities on a large scale will ordinarily resort not to its bank but to an enterprise sometimes affiliated with the bank, but more often independent, whose function it is to arrange for the sale and distribution of shares upon the necessary basis — soliciting and obtaining, of course, the financial aid and support of as many banks as may be needed in the operation. This type of transaction obviously grows to some extent out of the fact that the unit size of American business has increased much more rapidly than the unit size of banking. The statement holds good particularly of businesses that are borrowers on a large scale at banks.

Effect of Collateral Borrowing on Banking. But while an early divorcement was thus effected between investment and commercial banking, a divorcement only now approaching its end at least to appearance, American banks have for long years past been increasingly great lenders upon collateral securities. The general position of collateral loans in the banking structure has already been indicated.[1] What is here to be noted is the fact that the tendency to demand collateral as a basis for, or protection to, ordinary commercial loans has in many quarters reached a rather unduly expanded state, representing in many cases a slovenly attitude on the part of the banker because it reflected an evident indisposition on his part to assume the risks of credit analysis and of the extension of borrowing authority accordingly. Partly also it may be regarded as the outgrowth of the very wide distribution of savings and security ownership in the United States, and of the increasingly broad distribution of stocks and bonds, particularly since the close of the War. Whatever may be the explanation of it, the fact remains that at present not a few enterprises are disposed to obtain temporary accommodation from banks when they require it by pledging with such banks securities which were either carried as a part of working capital of the concern or furnished by the major stockholder or partners as a means of protecting corporate borrowing and at the same time of avoiding the necessity of supply-

[1] See *supra*, page 108 ff.

ing a detailed statement of condition. With the spread of stock-and-bond ownership and with the continued expansion of local stock exchanges, too, there has been an increasing tendency on the part of individuals to borrow at the banks on collateral securities. Such individuals tend to convert what in former years would have been savings accounts into stocks and bonds and when accommodation is temporarily needed, to borrow from the banks with these as collateral instead of as in former years reducing the savings account or perhaps obtaining a loan from the savings institution with the aid of a cosigner or an accommodation endorser. We have seen that these methods have tended to give to the portfolios of American banks a nominally less liquid character. It is to be noted also that, at the same time, they have also tended to develop a broader market for corporate securities than could otherwise have been expected to exist. Commenting upon one phase of the situation, the Federal Reserve Board in its report published March, 1927, remarks:

"Of the total loans and investments of all member banks on June 30, 1926, 16 per cent was eligible for rediscount at the reserve banks, and this proportion was 18 per cent for national banks and about 12 per cent for non-national member banks. For national banks this ratio is available for a series of years and is presented in the following table:

Eligible Paper Held by National Banks

[Amounts in millions of dollars]

End of June[1]	Total Loans and Investments	Paper Eligible for Rediscount	
		Amount	Per Cent of Loans and Investments
1918	14,129	3,218	22.8
1919	16,074	3,551	22.1
1920	17,817	4,320	24.2
1923	16,891	3,563	21.1
1924	17,123	3,542	20.7
1925	18,405	3,412	18.5
1926	19,260	3,497	18.2

"The decline in the proportion of eligible paper has been continuous and considerable and has been due chiefly to the rela-

[1] No data on eligible paper available for 1921 and 1922.

tively more rapid growth of holdings of investments and of loans on securities."

The tendency of things in American banking and the closer union of interest and sympathy which has been developed of recent years between investment houses and banking institutions as well as between the latter and the Stock Exchanges has undoubtedly contributed very greatly to the volume of stocks and bonds issued, which in effect means to the number of concerns that have assumed a corporate type of organization with a definitely developed capital structure as a result. Many concerns whose securities are ordinarily closely held and might in other circumstances have remained in the form of partnerships or of family-owned enterprises have been encouraged by the ease of corporate financing and of access to bank funds to establish a rather unstable or at times inflated capital structure and to bring about a more or less artificial " distribution " of their obligations. The movement toward corporate financing undoubtedly has some merits or advantages along with the corresponding demerits; but on whichever side the balance may be felt to lie, the outcome must be regarded as in no small measure the result of our special sort of banking development.

The Federal Reserve System moreover must be regarded as in some sense responsible, here as elsewhere, for dangers in American banking as well as for improvements of practice and condition. In not a few cases, banks have felt warranted in embarking upon investment operations and in putting a very considerable proportion of their assets into long-term loans upon the assumption that a certain portion of their portfolio was to be maintained in highly liquid form suitable for use in obtaining rediscount accommodation in federal reserve banks. In such cases the bank which so divides its assets has in effect set aside a definite portion of its capital for use in operations involving frozen paper because of a belief that it can at all times obtain prompt use of liquid funds by falling back upon reserve banks through the rediscount method. That this is not altogether a wholesome situation is the opinion of not a few observers, but it is none the less a recognized tendency.

Reorganization of the Money Market. The money market of the United States has been in process of reorganization and development during the past twelve years. Due to the peculiar and highly individualized structure of banking in this country, the American money market had long retained an extremely elementary struc-

ture. Prior to the organization of the Federal Reserve System, during the first three quarters of the nineteenth century, New York City was probably the only center in which anything like a true money market could be said to exist. Even in New York the market itself was extremely crude. There was little or no purchasing of commercial paper by the banks; and while commercial paper houses had attained some degree of development, the function was not exactly that of providing an outlet for floating funds, but was rather that of presenting a means of investing bankable funds to institutions whose immediate cash resources were temporarily in excess. Indeed a large part of the commercial paper of the country was sold outside of New York.

Within New York itself the call loan market provided the nucleus or basic factor for the employment of bank funds, and it was the call rate which was depended upon to indicate the general trend of money values. Exports and imports of gold were affected much more directly by changes in the call rate than by changes in actual bank rates. The absence of any central banking mechanism naturally prevented the development of any organized means of controlling or directing the market. With the establishment of the Federal Reserve System, conditions began gradually to change. Among other alterations was the introduction of the bankers' acceptance and the gradual building-up of a market for such acceptances. This development, however, has been very slow, and it is still true that the reserve banks themselves constitute the principal market for such acceptances. At present, the constituent institutions which participate in the money market are the various national and state banks, and a certain number of private banking enterprises which operate either domestically or in international trade, while to some extent insurance companies and savings institutions are also money market factors, either as investors or lenders or alternately as both. An effort has been made to develop institutions similar to the acceptance houses of Europe, but the experiment has been only partially successful, and such few houses of this kind as there are today play only a limited part.

Foreign banking organizations, although at one time promising to develop, have not been especially successful and the greater part of those which were formed during the war years have gone out of business. The call market, of course, continues its activities;

indeed at the present time fully three to three and a half times as much money is furnished by the banks to brokers as was the case before the War. The chief change that has been brought about by the working of the Federal Reserve System is thus seen in the fact that a certain element of bona fide paper representing commercial credit is actually traded in between banks, and between them and the reserve banks, such paper taking the form, usually, of bankers' acceptances. But the reserve banks themselves steadily buy, and occasionally sell, such paper, chiefly acceptances, as they may consider suitable for their operations. There has also, since the close of the War, been a considerable growth of a market for short-term government obligations — the so-called treasury certificates which are now largely held by commercial banks as a medium for obtaining rediscounts from reserve banks — while the reserve banks themselves buy and hold large quantities of such certificates as a means of earning an income. The Federal Reserve Board in its annual reports expressly speaks of operations in these certificates as the means through which the open-market policy of the reserve system is applied.

Outside of New York and the other eleven Federal Reserve cities there has been a somewhat parallel development running along lines similar to those which have been followed in New York. The difference has been that in none of these cities do the call market or the operations on the Stock Exchanges, which are associated with it, hold anything like the commanding position before the public eye which they occupy in New York. In fact there is no city where they may be said to be the controlling factor in the making of rates. In most of the Federal Reserve cities, moreover, the acceptance business has been but slightly developed, and banks which desire to purchase this kind of paper frequently obtain it from New York City, the local reserve banks themselves often finding such paper so short in supply that they enter the New York market for the purpose of purchasing the acceptances which are afloat there.

This of course means that money-market development, in the true sense of the term, is still in an extremely nebulous condition; this being, however, largely the result of the refusal or failure of reserve banks to become purchasers of the types of paper which are locally available or within their reach. They have almost invariably feared to enter into competition with large member

banks, and so fearing have naturally been inclined to allow themselves to lean upon the New York money market rather than to develop their own local dealings or to encourage the offering of paper to them by local producers of it. This undoubtedly has been a serious error; but, due to the peculiar structure of the reserve system, it was one which could not well be corrected, except through the activity of the Federal Reserve Board, and such activity has been steadfastly withheld or at times repressed. The local reserve banks, whose boards of directors were predominantly named by member banks, would hardly be expected to exert themselves vigorously, and the three members of each board, appointed by the Federal Reserve Board in Washington, have never been so chosen as to insure any vigorous effort, to develop the idea of a local open market. These factors explain why it is that the growth of such a market has been as seriously retarded in the United States as has been the actual case, though there is no reason why at any time at least the outlines of a money market should not be brought into existence in practically any of the Federal Reserve cities.

In these circumstances it is clear that, except for the limited current dealings in acceptances and except for the distribution of commercial paper on behalf of a relatively small number of commercial enterprises, the general borrowing public of the United States obtains its banking accommodation not through the money market but through direct bank discounting. It is a condition of affairs which probably will slowly but quite steadily change, and will eventually give place to a financial structure analogous to that existing in Great Britain.

Future of American Banking. The sketch which has thus been furnished of contemporary conditions in American banking shows that our system is in few respects closely comparable with that of any other country, yet that it is undergoing very much the same process of development that is being noted in many other countries. The tendency to centralization, the weeding out of small institutions either through purchase and merger or through failure has been characteristic of the past two decades, both in Europe and in other countries on this side of the Atlantic. The Federal Reserve System, although totally different in structure from the central banking systems of foreign countries, is nevertheless assimilating itself closely to the standard central banking type; and

although it has not succeeded in retiring the great body of national bank notes outstanding when it came into existence, it is none the less steadily progressing towards centralized control of the note issue.

Factors which prevent the assimilation of American banking to conditions and methods obtaining abroad are seen in the maintenance of forty-eight bank-charter granting agencies in addition to the central government and the continued maintenance of many varied types of bank-charter and bank-management requirements, notwithstanding the gradual approximation to a more uniform basis. Weight should also be given to the varied types of industry and agriculture prevailing in local areas throughout the United States and the consequent tendency to develop and maintain local banking centers which owe their existence not merely to decentralizing tendencies of an artificial type, but also to the fact that there is a certain amount of good reason for their existence in the fact of local peculiarities of industry and business. Another factor which makes against complete harmony between American and foreign banking method and practice is found in the so-called free banking idea accompanied by anti-branch bank legislation in many states, based upon the view that branch banking carried on by large institutions with headquarters at a distance tends to restrict or prevent the growth of local business through withholding or at all events lack of adequate credit facilities.

In spite of these facts the United States, partly as a result of the general prosperity and wealth, partly as the result of accidents, has succeeded in building up the greatest stock of gold in history and in developing a banking system protected by this stock of gold and possessing combined assets in the neighborhood of $60,000,000,000 whose general situation may be represented as follows:

SUMMARY OF THE COMBINED RETURNS FROM ALL REPORTING BANKS IN THE UNITED STATES, ALASKA, AND INSULAR POSSESSIONS, JUNE 30, 1926

Summary of reports of condition of 28,146 reporting banks in the United States, Alaska, and insular possessions at the close of business June 30, 1926

[In thousands of dollars]

RESOURCES

Loans and discounts:		
On demand (secured by collateral other than real estate)	3,473,823	
On demand (not secured by collateral)	1,069,315	
On time (secured by collateral other than real estate)	4,090,406	
On time (not secured by collateral)	7,973,254	
Secured by farm land	354,124	
Secured by other real estate	2,393,718	
Not classified	16,878,850	
Total		36,233,490
Overdrafts		49,470
Investments (including premiums on bonds):		
United States Government securities	4,060,468	
State, county, and municipal bonds	1,270,894	
Railroad bonds	1,626,180	
Bonds of other public service corporations (including street and interurban railway bonds)	1,123,265	
Other bonds, stocks, warrants, etc.	7,734,334	
Total		15,815,141
Banking house (including furniture and fixtures)		1,493,050
Other real estate owned		358,917
Due from banks		3,842,475
Lawful reserve with Federal reserve bank or other reserve agents		2,926,586
Checks and other cash items		926,109
Exchanges for clearing house		1,111,452
Cash on hand:		
Gold coin	40,711	
Silver coin	62,369	
Paper currency	599,180	
Nickels and cents	2,077	
Not classified	292,183	
Total	996,520	
Other resources		1,140,152
Total resources		64,893,362

LIABILITIES

CHAPTER IV

CHEMICAL INDUSTRIES

By Henry Wigglesworth[1]

Introduction. There exists a common misconception that the Chemical Industry is largely a foreign importation which, transplanted upon American soil in recent times, has with its untold opportunities abundantly rewarded those who had the hardihood and capital to embark upon it. That this error should be so general is not strange. Although the transfer occurred soon after the arrival of the first emigrants to this continent, few people ever come into direct contact with the industry itself, and even the purchase of the most common supplies of our daily life does not necessarily bring to light the vast mechanical and industrial organization which has had to be built up in order to attain such superiority in the product and economy in the distribution as we are privileged to enjoy. Chemicals are used by the individual in such trifling quantities that even for the expert it is not easy to visualize the industry as a whole.

Its early roots date back even before the Revolution. In 1770 William Molineaux is known to have established a complete dye house with a large assortment of dyes for coloring domestic fabrics. In 1830 J. L. Bishop records that there were at least thirty chemical establishments in the United States, with an aggregate capital of $1,158,000, making products of a value of $1,000,000 per year — a large sum at that time when the modern factory system was still fully fifty years from its inception.

The charter of the famous Chemical National Bank of New York, as its name indicates, at this early period contemplated an intimate association with the industry. About 1820 this bank had a small chemical plant, making sulfuric acid, at the foot of Bank Street on the Hudson River. Three years later the manager,

[1] Formerly Director of Development, General Chemical Company.

Martin Kalbfleisch, who had been educated in Holland and France, was making dry colors, Paris green and yellow prussiate of potash.

The chemical industry has always required a high degree of scientific ability, ingenuity, and even altruism. Within its scope are included all such manufactures as involve changes in the nature of the material itself — changes accomplished by chemical forces, and not merely changes of external form due to mechanical operations. It calls first upon the professional chemist for its inception. The work is pushed forward by its practical chemists and engineers so as to extend its broadening frontiers. Its activities have grown simultaneously with our advancing knowledge and the needs of modern civilization until it now ranks second to none in point of achievement and third, or at least fourth among American industries in statistical importance.

The Government recently rated the 1925 production of iron and steel at a value of $6,461,668,000; chemicals at $6,439,000,000. Some idea of what this means and of the diversity of its fields may be gathered from the following summary, giving Chemical and Metallurgical Engineering's estimate of the value of chemical production for 1926:

Acids, Heavy Chemicals and Coal Tar Products	$655,274,829
Explosives	75,029,127
Fertilizers	182,088,751
Gas, manufactured	450,097,161
Glass	309,353,411
Paper and Wood Pulp	907,346,992
Sugar Industries	871,736,338
Soap	276,402,838
Tanning Materials and Natural Dyestuffs	25,971,612
Wood Chemicals and Charcoal	29,695,423

The capital required to effect the transformations included in this tabulation and to market the products can be estimated conservatively at twice these values or about twelve billion dollars. This gives a fairly accurate picture of the immensity of the supplies necessary for what might be called the digestive system of American industrial life. Here is an intermediary industry whose function is to take the raw products of nature and convert them to forms essential for further development and manufacture, and its progress has so far required all the capital that could be attracted or applied from profits. The demands made upon it have at

times even required heavy imports, but these have grown less and less and are now chiefly limited to pharmaceuticals, perfumes, soaps, and special dyes.

The industry is fundamentally international because of its scientific background, which brings about cordial international relationships. John Tyndall referred to this scientific basis of industry when he said: "Behind all our practical applications, there is a region of intellectual action to which practical men have rarely contributed, but from which they draw all their supplies." No branch of the industry can suddenly spring forth without a prolonged, laborious, and earnest effort to give reality even to the most alluring conceptions. The jump from academic experiment to the finally perfected industrial mechanism is generally long and costly. Even the importation of perfected foreign processes is in itself an expensive procedure, for the specialist of one country can not quickly transfer his skill to another. The personnel to be trained will only slowly absorb the rationale of the various steps, and false moves and misunderstandings soon aggregate into large losses. The active and continuous research which has made the German an exemplar of chemical progress is now more than ever the only true policy of progress.

The chemical industry has kept pace with the advance of civilization. As early as 1608 attempts were made by the early Virginians to manufacture tar, potash, and glass, the last forming part of the first export shipment from America, and in 1620 iron, salt, and leather were actually being made in Virginia.

England promoted the industrial life of her Colonies. The courts of Massachusetts in 1642 established saltpeter houses to supply that essential of gunpowder. In 1648 John Winthrop, Jr., was commissioned to manufacture salt. Two years later he planned the first chemical stock company on record in America, for the purpose of manufacturing saltpeter. In 1651 he was granted the first monopoly by Connecticut for working lead, copper, tin, vitriol, alum, etc. Boston and Philadelphia, then the most important cities on the Continent, were engaged in independent efforts to supply potash leached from hard-wood ashes, as well as sodas, oil of vitriol, and acids generally.

The impracticability of importing acids in sailing ships when fragile glass carboys were the only containers known, their breakage frequently causing risk to ships, passengers, and crew, early com-

pelled the production of oil of vitriol and nitric acid on a small scale. Operations at that time were little more than laboratory processes with glass stills and alembics unsuitable for a great output. Small laboratories, however, existed in each important community, offering a way to study the chemical problems that were rapidly increasing.

In 1704 the British Parliament offered bounties for the production of tar, pitch, and turpentine. In 1707 South Carolina passed a law to encourage the manufacture of saltpeter and potash. The Southern settlers lived then between the sea coast and the Alleghenies, depending upon their plantations of tobacco and cotton. The culture and extraction of indigo for dyeing, introduced by Eliza Lucas of South Carolina in 1741, was the beginning of natural dyes in America. The Colonies grew more and more self-contained, and the effect was felt in Great Britain, so that in 1770 further promotion of America's commercial independence was deemed unwise, and the rapid changes of policy that ensued brought about the American Revolution.

Shortly after the Revolution Caleb and Joseph Wilder perfected a process near Boston for the manufacture and recovery of potash. This was before the Patent Office was established, and it is interesting to note that the first patent ever issued in this country protected this operation.

John Harrison of Philadelphia was the first manufacturer of chemicals. He commenced operations in 1793, two years later going to Europe to familiarize himself with the processes then employed. A chamber system of a capacity of 40,000 lbs. of oil of vitriol per annum was built in 1806, which is about the same capacity a single unit would now have in one day. That step naturally led to the concentration of chamber acid to oil of vitriol in platinum, the suitability of platinum having been discovered by Wollaston, a Philadelphian. Charles Lennig subsequently erected much larger chambers at Bridesburg, near Philadelphia, his successors manufacturing there to this day a very large number of chemicals. Nine years after John Harrison started, Thomas Jefferson induced E. I. du Pont de Nemours to embark in the manufacture of explosives at Wilmington, Del., then a safe distance from population. The purchase in 1920 by the Dupont Company of John Harrison and Sons Company marks an interesting amalgamation of these historic efforts.

James Woodhouse founded the Chemical Society of Philadelphia in 1792. It was the first chemical society ever formed in the world, and proved that America was alert to the opportunity science afforded. Thomas P. Smith in his annual oration to the Chemical Society in 1798 said: "The only true bases on which the independence of our country can rest are agriculture and manufactures. To the promotion of these nothing tends in a higher degree than chemistry."

In 1801 Dr. Robert Hare discovered the oxyhydrogen blowpipe, opening up the way for future operations of the blast furnace and the modern oxyacetylene torch. Benjamin Silliman, about this same period, was the first to use the voltaic arc, and following Sir Humphrey Davy's work, succeeded in separating potash from sodium. These important contributions serve to illustrate the character and ability of America's early chemical leaders.

In 1815 when the war with Great Britain had ended, immense importations of foreign chemicals and other goods threatened the small domestic manufacturer, and the clamor for Congressional action and protection started in so effectively that the following year the first tariff bill for protecting American chemical industries became law. The crystallization of a definite sentiment in favor of industrial independence and reasonable protection being assured, many new activities were quickly promoted. Gas lighting on a large scale was first introduced in 1816 in Philadelphia, Washington, Baltimore, and other cities, making possible the future coal-tar industry here.

In 1818 the movement in the West had stimulated beyond the Alleghenies a demand for acids and other chemicals, and their manufacture was begun by the Grasselli family at Steubenville, Ohio. This move was vastly more important than its founders could possibly have conceived, as the great oil and steel industries of Pennsylvania, Ohio, and the Middle West were destined to become the very largest consumers of sulfuric acid and other chemicals. Subsequently this early Western chemical manufacture became the Grasselli Chemical Company, a powerful factor in both chemicals and zinc.

Medicinals were not neglected, for in 1822 Rosengarten and Sons established themselves in Philadelphia, in the general line they are still following. In 1829, William Weightman, a young Englishman, sought and took employment with Farr and Kunzi, manu-

facturing chemists of Philadelphia, and lived to become the successor to that firm. After his death, at the age of ninety-one, these two companies merged. It is a notable example of the advantages accruing from a traditional persistence in one business. George D. Rosengarten, now President of the American Chemical Society, and his brother Adolph, continue in their leadership, making preparations of bismuth, strychnine, quinine, mercurial salts; as well as ether, morphine, codeine, and other anæsthetics and opiates.

Sulfur. Prior to 1907 the United States was practically dependent upon Sicily for its supply of sulfur. A small quantity came from England, the result of a chemical process which gave a "recovered sulfur," and some from Japan.

About 1896 Herman Frasch had brought his experiments in melting underground and then pumping molten sulfur to the surface from Louisiana deposits, warranting the formation of a company to develop the enterprise. The Union Sulphur Company was formed with ample capital, and work proceeded until in 1901 production on a small scale started. From 1903 to 1907 what might be termed a trade war continued with the Sicilian product, but the superior quality and low-production cost of Louisiana sulfur made competition on the part of the Sicilians useless. The Sicilian sulfur was mined in a crude, laborious way and had to be refined in this country, to obtain pure or technically pure sulfur. For this reason practically all the refineries, other than those on the Pacific Coast, were located in the vicinity of New York, at the port of entry.

From 1907 to 1914 the Union Sulphur Company supplied practically all the sulfur used in the United States except a very small quantity imported from Japan. Crude sulfur, *i.e.*, brimstone, was and is duty free, but the American product, which is about 99.5 per cent pure and free from arsenic, selenium and tellurium, makes competition impracticable. The value of the immense deposits of sulfur in our Southern states, along the Gulf of Mexico, and in the state of Texas, can scarcely be estimated. This was brought home to us with startling force at the outbreak of the World War.

Union Sulphur Company was then in full operation, and increased its output up to some 4500 tons a day, so that when the United States did finally declare war there was on the surface immediately available well over 1,000,000 tons. This immense supply

was of the greatest value not only to the Government of the United States and Canada but to England and France for munition production. This tremendous demand upon the Union Sulphur Company deposits in Louisiana practically depleted the supply. None has been mined there for some two or three years and the mines have been abandoned, though the Union Sulphur Company is said to be exploring actively for a suitable supply.

The Freeport Texas Company started in 1911 and began active operations in 1914, using modifications of the Frasch process, but it was some years before production on a really large scale was obtained, due partly to physical difficulties which had to be overcome. This company now produces a very large quantity of sulfur of the highest quality.

The Texas Gulf Sulphur Company was formed in 1919, and rapidly pushed forward to the position of the largest producer in the world.

Fortunately for the United States and in fact for the world at large, there seems every indication of the Texas supply being adequate for all demands for many years to come, both Freeport Texas Company and Texas Gulf Sulphur Company having large reserve deposits still untouched. It is a curious fact, apparently unique, that Frasch's process operating from 900 to 1200 feet underground is cheaper than any open-cut or underground mining so far developed.

Thus the economical method of the Frasch process, of forcing superheated water down to and melting the underlying deposit, combined with the purity of the product, enables the United States now to supply 85 per cent of the brimstone used by the entire world. After the Sicilian sulfur ceased to be imported and the supply of domestic sulfur was proved adequate, refineries were built at various advantageous locations. Grinding plants for handling the excellent American product were also installed, affording an ample supply of sulfur in all forms for the demands of the United States and Canada as well as for export to almost every foreign country.

The importance to the United States of this great supply of superior brimstone can readily be imagined when a few of the uses of sulfur are considered. Besides the manufacture of sulfuric acid for many and varied uses and sulfite for paper making, brimstone is largely used either in crude form or refined in the fertilizer trade, in

fungicides and insecticides, in rubber manufacture, in bleaching of all kinds of fruits, sugar, fabrics, etc., in explosives, and in matches; in fact combined sulfur in some form enters into the production of practically every manufactured article, which no doubt prompted the old saying that " The civilization of a country may be gauged by the extent of its use of sulfuric acid."

Sulfuric Acid. Sulfuric acid is made by two processes — the chamber process originally developed in England, and the contact or catalytic process originally developed in Germany. The chamber process turns out a product of moderate concentration and is valuable and suitable for many purposes as it is also capable of concentration when desired; whereas the contact process turns out normally a product of practically 100 per cent, which is required in increasing quantities by the industries.

Chamber acid was made in this country as early as 1793, and is still the principal mainstay of fertilizer manufacturers for converting phosphate rock into acid phosphate. Both processes require sulfuric dioxide made by burning sulfur or sulfur-bearing ores with a regulated amount of air. In addition the chamber process needs water and nitric acid, the latter obtained from sodium nitrate (Chile saltpeter), or more recently from oxidation of ammonia. This process is also largely used in the recovery of the sulfur dioxide from smelting operations.

The contact process does not require any nitric acid because the platinum catalyst makes it possible to combine the sulfur dioxide with the excess air to sulfur trioxide, which, with water, forms sulfuric acid of practically any strength desired. The platinum catalyst, however, may become inactive or poisoned by impurities present in the gas produced by burning sulfur-bearing ores, and in this case extensive and costly purification methods have to be employed. Where the raw material for the contact process is in the form of pure sulfur, these difficulties do not exist.

At first sulphuric acid was made only from sulfur imported from Sicily. Then came a period when pyrites, chiefly from two great English companies mining this ore in Spain for its copper, undersold Sicilian sulfur and rapidly displaced it. Pyrites and other sulfur-bearing ores contain arsenic lead and other impurities and hence yield sulfuric acid of insufficient purity for general uses. This grade of acid then became known as pyrites acid and was

employed chiefly for dissolving phosphates and for oil refining. The consumption for this purpose grew enormously year by year, and each of these industries found it profitable to embark in its manufacture. The chemical manufacturer proper resorted to purification methods to remove the arsenic and to distillation, but both of these required skill and close supervision, so that sulfur was never entirely displaced as a raw material.

The United States did not develop pyrites ore bodies comparable with the great Spanish deposits, but Canada, Virginia, and California each supplied a quota and the supply grew until one half of our requirements was of domestic origin. Meanwhile the smelting of copper and zinc was rapidly expanding in our Western States, and these ores generally carried enough sulfur to produce sulfuric acid economically, but the freight charges due to the long haul to consuming districts were prohibitive, so for nearly fifty years great expense was incurred in the West to discharge the sulfur gas (sulfur dioxide and air) where it would do the least harm, while at the same time the East was importing the same raw material from Europe at an expense of millions of dollars. With the extension of our industries westward and more particularly with the rise of oil refining, an acid demand has sprung up in the West. The New Jersey Zinc Company, Matthiessen and Hegeler Zinc Company, and other zinc smelters, and the American Smelting and Refining Company, the Anaconda Copper Mining Company, Phelps-Dodge and Company, and other copper smelters are now utilizing a small part of the great volume of waste sulfur gas, and they will, as the demand increases, expand their operations. There is now produced from this source one and a half million tons of by-product sulfuric acid annually.

There now exist in America contact plants built during the last twenty-odd years, having a total annual capacity of over two million tons of sulfuric acid, all of which can be turned out at strengths apparently considerably over 100 per cent. This apparent anomaly is caused by the fact that contact acid, or oleum, as it is called, consists of a solution of sulfur trioxide in sulfuric acid and is capable of absorbing water to yield a greater weight of true sulfuric acid.

The Badische Aniline and Soda Fabrik of Germany, after ten years' study and development, was the first to manufacture this acid. It found oleum necessary for its dye production, and spent

millions until success was assured. The patents for this process made their appearance about 1899. Mr. August Hecksher of the New Jersey Zinc Company, through a personal friend, Herr Grillo of Darmstadt, was informed that Schroeder and he had a different process which they were willing to introduce into the United States free from patent interference.

It happened therefore that the first contact acid plant was erected at Mineral Point, Wis., by a subsidiary of the New Jersey Zinc Company, who had little or no experience in the manufacture of any chemical. The plant was crude and the product impure, but it served to put this great corporation into sulfuric acid manufacturing and at the same time awakened the older chemical manufacturers to the importance and practicability of the new process. The Badische Company, on the other hand, believing in the superiority of its process, demanded terms which were rejected by all whom they approached.

The General Chemical Company, a consolidation of eight companies with about a dozen plants, set about developing a process which would be free from existing patents, and succeeded to an unexpected degree, excelling even the remarkable work of the Germans. Their success brought about an agreement with the Badische Company and the acquisition of their contact patents.

The contact process bears little resemblance to the chamber system which was unaffected in its operations whether the gas supplied to it was from pure brimstone, free from serious impurities, or from pyrites and contaminated with arsenic acid and solid particles.

The catalyst must be equally protected from any solid or gaseous poison. The purification system had to be elaborated upon until it would pass the Tyndall ray of light test and show academic purity. This process can best be commenced with lead vessels and lead connections, but after the gas is perfectly purified and dried with strong sulfuric acid, lead can no longer be used, as a low red heat is necessary to carry on the final reaction. The product is anhydrous and its condensation must be effected either with 98 per cent sulfuric acid or one of the fuming grades. Weak acid cannot be employed effectively. There is no concentration system involved in the operation but only carefully controlled absorption of the anhydride, which is of singular purity. The trouble is to get a pure gas for catalyzing, whereas in the chamber system it is the final step of concentration that is the most exacting.

The Standard Oil Company experimented on the fuming grades of sulphuric acid and found that the asphalt base petroleums of California yielded to this acid to a degree then unknown. They therefore adopted the use of contact acid. The Texas oil fields in their turn also demanded this strong acid.

Approximate Consumption of Sulfuric Acid by Industries

	Tons per Month Calculated as 100% Sulfuric Acid	Percentage of Total
Fertilizers	111,000	42.3
Oil Refineries	35,000	13.5
Chemical and Drug Manufacture (including Ammonium Sulfate)	38,500	14.8
Steel Pickling and Galvanizing	36,500	14.1
Explosives	10,000	3.8
Fabrics and Textiles	5,200	2.0
Paints, Lithopone, Glue, etc.	5,300	2.1
Metallurgical (including Storage Batteries)	15,200	5.9
Miscellaneous	3,800	1.5
	260,500 tons per mo.	100%

Sulfates and Muriatic Acid. The ambition of every sulfuric acid producer is to become a consumer also, so that he can increase the number of his products and thus spread his risk. The decomposition of common salt with sulfuric acid results in the muriatic acid and salt cake of commerce, scientifically known as hydrochloric acid and sodium sulfate, both of which are largely used in other chemical processes and in glucose, glass, etc.

The manufacture of alum for paper making and water purification is another very large consumer of sulfuric acid, not less than six large corporations being engaged in the production of several hundred thousand tons per annum.

Blue vitriol (sulfate of copper) and green vitriol (sulfate of iron) are both large consumers, but these are now by-products of copper refining and of iron pickling so that they have become unavoidable products of other industries.

All the white lead used everywhere for paints was made with acetic acid prepared from acetate of lime and sulfuric acid, but recently synthetic acetic acid is taking its place.

These three products illustrate the ever changing picture of the chemical industry and the importance of varying products both for diversity of output and to maintain in the organization representative men familiar with current industrial and scientific progress, who can subdivide the responsibility of passing intelligently on the many opportunities and proposals that are submitted to every large corporation.

Fertilizer. The fertility of the soil is not easily maintained when each season's crops are sold and distributed far from the farm. It is a constant and serious problem for the farmer to replace the essential elements of plant food thus removed. Liebig, the renowned German chemist, revealed the need of soil nutrition early in the nineteenth century, and now it is generally recognized that phosphorus, potash, and nitrogen are the chief elements requiring replacement. The vast fertilizer industry predicated on this knowledge has been developed since this period. Seven and a half million tons of fertilizer are now used annually in the United States, and proportionately greater quantities in the older countries of Europe.

The original source of phosphorus for fertilizer was bone, but now it is almost wholly phosphate rock. In its natural form, this form of phosphorus, even where finely ground, is not available to plant life, and chemical treatment must be resorted to in order to render it soluble. The rock is ground first to an impalpable powder, then slowly mixed with nearly its weight of chamber sulfuric acid and allowed to mature in bins until the chemical reaction between the two is completed.

The development of the South Carolina phosphate deposits began in 1867, and until 1888 they furnished ninety per cent of the world's supply, and one hundred per cent of the American requirements. Then Florida entered the field, and by 1894 was producing 327,000 tons of phosphate rock, which was more than the South Carolina production. In 1893 deposits of phosphate were discovered in Tennessee, and by 1899 its production had also surpassed that of South Carolina. South Carolina could no longer compete economically and its production decreased to 100,000 tons in 1912, and in 1922 had ceased entirely. The use of the Florida phosphate has continued to increase, its present annual output being about two and a half million tons, or about 85 per cent of the total American production. In the conversion of this vast amount of

phosphate rock to acid phosphate, two million tons of sulfuric acid are required annually.

In addition to this great demand, there is a large consumption of phosphate rock in the steel industry and for the manufacture of pure chemical salts, such as mono-, di-, and tri-sodium phosphates, of which more than forty thousand tons are made annually. Pure phosphoric acid, which is widely used, is manufactured from phosphate rock by the use of the electric furnace. Recently its use has considerably progressed, replacing sulfuric acid in the production of concentrated or double-strength acid phosphate. This comparatively new development is attracting the farmer's interest more than usual on account of the economy offered by its cheaper transportation and handling.

The chief source of fertilizer potash has been the Stassfurt salt deposits of Germany and those of Alsace Lorraine. Recent developments in America, brought about by the shortage of potash during the War, have opened up sources of this element in districts remote from the farms. The American Trona Corporation (now known as the American Potash and Chemical Corporation) at Searles Lake, Calif., financed by English capital, was successfully engineered by Dr. John E. Teeple, and is supplying approximately ten per cent of our requirements of potash, and in addition is making borax and boric acid for the general trade.

Nitrogen in combined form for fertilizer has been supplied in the past chiefly from the immese beds of natural sodium nitrate in Chile. The greatest production of Chilean nitrate was reached in 1917 when three million tons were marketed. The present annual producing capacity is two and a half million tons, or 465,000 tons of actual nitrogen, of which the United States consumed in 1925 about 45 per cent. In addition to imported sodium nitrate, approximately 130,000 tons of nitrogen from other sources were used, the greater part being by-product ammonia of 12,000 coke ovens scattered wherever steel is made in great blast furnaces.

Only part of this ammonia and sodium nitrate finds its way into fertilizers, as immense quantities are consumed for making nitric acid in the manufacture of explosives, nitro-cellulose, celluloid, lacquers, photographic films, etc., but by far the largest part is used as plant food. The recovery of by-product ammonia from coke ovens and the fixation of atmospheric nitrogen, as well as other major uses for it, will be discussed later.

No branch of the chemical industry has faced more complex financial problems than fertilizer manufacturing. Sooner or later it is confronted with the true, economic condition of the farmer, whether that has been caused by a succession of poor crops or low prices for his products. For many years long extension of credit was permitted in the belief that it was the manufacturer's proper problem, but it proved so disastrous to many corporations that in recent years practically a cash business has been carried on. There still remains, however, the problem of adjusting the continuous operation of manufacturing two million tons of sulfuric acid and furnishing raw materials to the uncertain needs of the farmer, which he only determines when spring sunshine pushes him to a decision. The fertilizer manufacturer can, therefore, only plan his year's purchases upon averages.

Many years ago the great Chicago meat-packing houses of Armour and Company and Swift and Company undertook the manufacture of fertilizers in order to dispose of the scrap and tankage of their slaughter houses. To a large extent this policy is no longer relevant, as this by-product can now be disposed of, when properly prepared, at a much higher price, for feeding hogs and cattle. The menhaden fisheries, after extracting fish oil, also dispose of much scrap, such scrap being highly nitrogeneous.

The petroleum refiner with the problem of sludge acid disposal embarked in the manufacture of acid phosphate. The Standard Oil Company, forming the Liebig Fertilizer Company, made a very large tonnage until methods were developed for purifying the acid from tar and oil and then concentrating it for re-use in its own petroleum refining. It subsequently then sold its works to the fertilizer corporations.

Fixation of Nitrogen. Plant and animal life, when supplied with the warmth and rays of the sun, has always been Nature's great laboratory for the fixation of nitrogen. The effort to accomplish a similar result by synthesis, until this century, was not practicable, notwithstanding the availability of the air with 75 per cent free nitrogen and of water, constituting over 60 per cent of the world's surface, which could not be persuaded to yield up oxygen and hydrogen separately to lend their part in the combination.

The development of the electric arc in the last thirty years made possible high temperatures that were formerly uneconomic or impossible. And out of this there has been developed the process

of burning the nitrogen composing the air with its associated oxygen, forming nitric oxides, which can subsequently be absorbed as nitric acid.

The first attempt to combine nitrogen and oxygen by means of an electric arc on a manufacturing scale was made by Bradley and Lovejoy at Niagara Falls, N. Y., in 1902–03. With more financial support they would probably have been completely successful. A year or two later, Professor Birkeland of Stockholm, used a different arc furnace, which stimulated a greater financial interest, and in 1907 a commercial plant was erected at Notodden, Norway. The Norsk-Hydro Corporation acquired the Birkeland patents and plant and erected a much larger works at Rjukan, which is the most important plant of this type in the world, because of the high efficiency of the Birkeland furnace and the cheap water power in Norway. At the same time the Badische Aniline and Soda Fabrik of Germany was developing the Schonherr vertical arc furnace and erected a trial plant at Christiansand in Norway, ultimately combining with the Norsk-Hydro at Notodden. Subsequently, the Badische, having successfully developed the synthetic ammonia process, sold its interests in the Norsk-Hydro enterprise, which is now chiefly French and Norwegian capital with Norwegian management.

Two other German arc furnaces of interest were invented, one by Pauling and the other by Siebert. The Pauling process was acquired by the Duke interests in the United States, and a plant was erected and operated for some time at Great Falls, S. C. The Birkeland process was tried by the Dupont Company, but owing to the higher cost of power and the higher cost of construction in the United States the arc process was abandoned. A small plant at LaGrange, Wash., has been able to operate, however, for some years, fixing 300 tons of nitrogen as sodium nitrite.

The Siebert process used by the Nitrum Company at Rhina near Zurich, Switzerland, is still operating with cheap off-peak power. This process mixes pure oxygen with air in order to increase the yield of nitric oxides. The extent to which the arc process has been developed may be judged by the fact that the Norsk-Hydro uses about 400,000 horse power continuously, producing chiefly nitrate of lime and nitrite of soda.

The liquefaction of air and its fractional distillation separating oxygen from nitrogen release enough nitrogen to make it economic

for various commercial uses. Among the most important is the production of calcium carbide, which at high temperatures absorbs nitrogen, producing calcium cyanamid.

The Cyanamid process was invented by two German chemists, Dr. Adolph Franke and Professor Nicodem Caro. The first commercial plant was put into operation about 1906. The product being used directly as a fertilizer led to great expansion of this industry and very large plants were erected in Germany and in Norway. In America the process was acquired by the American Cyanamid Company which now produces at Niagara Falls twenty-five thousand tons of nitrogen annually, converting the cyanamid into ammonia, selling the products as such, as well as compounded for fertilizers.

Even as late as during the War this process was selected by the Government as the furthest advanced in nitrogen fixation and most reliable for the manufacture of synthetic nitric acid in case shipments from Chile ceased. About $60,000,000 was expended at Muscle Shoals for a large factory, but this has not been employed for peace-time operations.

The third fixation process, now the most important, is the direct combination of hydrogen and nitrogen to form ammonia. This process was of much older origin in its conception, but it was not until Professor Haber actually constructed a small plant in Germany that its commercial feasibility was acknowledged. The Badische Aniline and Soda Fabrik immediately retained Dr. Fritz Haber for its further development, securing world rights to all his patents. Haber originally used catalysts like uranium and osmium, which were expensive and difficult to manipulate, whereas Badische developed a very cheap and simple catalyst of fused iron oxide to which it added small quantities of certain alkaline earth oxides.

The Badische's first commercial plant in Ludwigshafen was completed late in 1911. Later it built a much larger plant at Oppau near Ludwigshafen, completed during the first year of the War and surrounded with much secrecy. It also constructed during the War a very large plant at Merseburg. It was not until the Allied armies advanced to the Rhine in 1919 that the full measure of their success became known to the world. The magnitude of the enterprise can be judged by the fact that they are now manufacturing one thousand tons of ammonia per day, with a capital investment in these two plants of over $70,000,000.

At the same time the problem had been seriously studied in America by the General Chemical Company, which by 1916 had made such progress that it decided to appropriate about $1,000,000 for a manufacturing unit which was to be erected in the vicinity of New York. Before the apparatus had been delivered, the United States had entered the War and the Government solicited the privilege of erecting a plant of ten tons daily capacity. This was the first synthetic ammonia plant in America. It was completed at Muscle Shoals, Ala., shortly before the Armistice and made a small output just sufficient to demonstrate its practicability. The Atmospheric Nitrogen Corporation was thereafter formed by the General Chemical Company and the Solvay Process Company, and a plant built at Syracuse, N. Y., which is still operating.

In France, Georges Claude had also worked out a process of combining nitrogen and hydrogen to ammonia. The American rights of the Claude process are owned by Lazote Inc., a subsidiary of E. I. du Pont de Nemours and Company. An initial plant with a daily capacity of twenty-five tons of anhydrous ammonia has been constructed in Belle, W. Va., in the heart of the soft-coal region, and commenced production of ammonia in the spring of 1926.

There are now eight plants in the United States using these processes, with a rated annual capacity of more than thirty thousand tons of combined nitrogen. Part of this growth is the result of utilizing hydrogen released as a by-product. The competition has made the lowest prices for ammonia that the farmer and consumer have ever enjoyed.

Alkali. Alkali manufacture in this country did not assume great importance until 1884. The ocean imposed no such difficulties upon its transportation as it did upon acids, and Europe supplied our wants. The Le Blanc process which had such a tremendous influence in the expansion of the European chemical industry, was never used here, as the new ammonia soda process was selected in preference to it. W. B. Cogswell, a mining engineer, financially assisted by Rowland Hazard, a distinguished citizen of Providence, R. I., had had the honor of establishing the newer process in 1884 much as it exists today.

The great industry was introduced by transplanting it through agreement with the Belgian firm of Solvay and Company. It was the first conspicuous example of international chemical relations

which have been maintained in the United States for over forty years. It must not be assumed that transplanting a process from Europe to America was a simple affair. No precautions can be overlooked in such a problem. Highly competent men were selected to go to the Solvay's French Works at Dombasle and remain there until each step in the operations was mastered. The initial plant was finally started January 10, 1884, with what was expected to be a capacity of fifty tons per day. This tonnage was not obtained with American workmen accustomed to labor-saving devices, and many new and novel improvements had to be developed which ultimately made possible a tonnage of one hundred and fifty tons per day with practically the same elements.

In 1892 the Ford family engaged in the glass business near Pittsburgh, Pa., organized what is now the Michigan Alkali Works, locating their plant at Wyandotte, Mich., on account of the brine wells of that district. In 1893 the Mathieson Alkali Works was also organized, locating its initial plant at Saltville, Va. This ammonia-soda plant was started with American capital under English technical direction and with a great deal of English machinery.

The Mathieson Alkali Works in 1895 installed a trial plant at its Saltville works for the manufacture of bleaching powder and incidentally caustic soda by the Castner electrolytic process which, proving successful, led to the erection in 1897 of a much larger plant at Niagara Falls, with a capacity of ten tons caustic soda per day. It was the first important electrolytic alkali plant in the United States, manufacturing caustic soda and bleaching powder, and incidentally was one of the pioneer industries utilizing Niagara Falls power. The growth of this process has been steady, but the disposal of the chlorine sets a limit to the caustic output. It is, nevertheless, one of the largest electrochemical plants in the world.

New management of the Mathieson Company after the 1921 business slump, directed the operation of the Niagara Falls plant towards replacement of bleaching powder (chloride of lime) by liquid chlorine, and in addition to this installed a synthetic ammonia plant to utilize the hydrogen which had for the most part been going to waste.

In 1899 the alkali consumers became dissatisfied to remain purchasers, and the Pittsburgh Plate Glass Company with its

large requirements of soda ash organized the Columbia Chemical Company, building a large plant at Barberton, Ohio. This company's production of soda ash is largely consumed by the parent company, but it is also a large distributor of caustic soda and soda ash. In 1910 another group of glass manufacturers, consisting of the Macbeth-Evans and the Flackus interests of Pittsburgh, together with the Hazel-Allas interests of Washington, Pa., and with a large soap company at Cincinnati, Ohio, organized the Diamond Alkali Company, whose headquarters are located at Pittsburgh. This company expanded during the War, until now it is one of the largest American companies.

The following table gives the output of this branch of the industry in 1925:

	Annual Production
Soda ash	1,810,000 tons
Caustic soda	492,000 tons
Chlorine (liquid)	37,500 tons
Bleaching powder	100,000 tons
Ammonia	144,700 tons

The distribution of soda ash in 1925 is as follows:

Glassworks	520,000 tons	28.8%
Caustic soda	465,000 tons	25.6
Sundry chemicals	185,000 tons	10.3
Soap	155,000 tons	8.5
Sodium bicarbonate	100,000 tons	5.5
Cleansing compounds and modified sodas	100,000 tons	5.5
Pulp and paper	75,000 tons	4.1
Water softening	75,000 tons	4.1
Textiles	35,000 tons	1.9
Petroleum	25,000 tons	1.4
Exports	16,000 tons	0.9
Miscellaneous	59,000 tons	3.4
	1,810,000 tons	100%

Two general methods practiced in alkali manufacture lead ultimately to identical results. The ammonia-soda process consumes salt, lime, and carbon dioxide, the ammonia used being recovered. The product is first sodium bicarbonate, which can be converted to carbonate (soda ash) by heating. The chlorine in the salt is lost or made into the by-product, calcium chloride. To convert the soda ash to caustic soda requires quicklime, and a practically valueless by-product of calcium carbonate is obtained.

Various types of cells for the electrolytic caustic soda process are used, the mercury cell producing the purest caustic. Each cell

requires a high quality salt and electric current, yielding dilute caustic soda, chlorine, and hydrogen. The chlorine is the chief economic factor justifying the electrolytic process and is of sufficient importance for special reference later. The hydrogen by-product is being used as a source of this element for ammonia synthesis and for the synthesis of other valuable compounds such as methanol. The direct combination of hydrogen and chlorine yields ten per cent of our national requirements of muriatic acid.

Borax. In connection with the alkali industry, the production of borax (sodium borate) must be mentioned. Its manufacture began in 1872 after the finding of deposits in a raw and impure state at Teels Marsh, Esmeralda County, Nev. In 1882, large deposits of colemanite (borate of lime) were discovered in Death Valley and at Daggett, Calif., which have since been of great importance in supplying American markets. Recently the recovery of potash from the brines of Searles Lake, Calif., has yielded immense quantities of borax as a by-product, and other deposits of colemanite in Nevada have been discovered. The Death Valley operation has been carried on by the Pacific Coast Borax Company, which was the pioneer in this industry, and that at Searles Lake by the American Trona Corporation, now the American Potash and Chemical Corporation.

Borax is used in the manufacture of glass, boric acid, soap, and vitreous enamels, as well as in tanning. Vast quantities of it are obtained in Italy from volcanic sources, but the United States produces considerably more than half of the world's consumption.

Chlorine. Bleaching powder was first made in Scotland in 1799 by Charles Tennant by passing chlorine over lime, the latter being the only practicable and convenient carrier for the former, as liquefaction had not yet been worked out. Bleachers of textiles were then the chief consumers, and a tradition was built up that the lime played a necessary part in textile bleaching. This tradition, born of the use of lime boiling and other lime treatments of textiles long prior to the use of chlorine as a bleaching agent, persists to this day, especially in England, but the use of bleaching powder in textile processes in Germany and the United States is obsolete, except for small-scale operation. As early as 1847, Charles Lennig made bleaching powder at Bridesburg, Pa.

The growth of the textile industry and of paper and pulp manufacture, both requiring bleaching powder for whitening their

products, made it desirable to have a domestic source of bleach here to avoid the losses of chlorine by storage and the dangers of importation. However, England was able to supply it so cheaply as a by-product of the Le Blanc soda process that domestic makers were discouraged from undertaking its manufacture until they, too, could simultaneously produce some other product. The electrolytic manufacture of caustic soda from natural brines offered this opportunity, and the by-product chlorine was for years marketed after absorption in lime as the bleaching powder of commerce.

The first electrolytic chlorine in the United States was made at Rumford Falls, Me., in February, 1893. This plant, known as the Electro Chemical Company, was replanted at the works of the Burgess Sulphite Fibre Company at Berlin, N. H., the Le Sueur cell being selected. At Midland, Mich., where the Dow Chemical Company is located, small quantities of bleaching powder were made in 1895, and by Thanksgiving Day, 1897, a plant using a current of four hundred kilowatts was put into operation. The Castner Electrolytic Alkali Company began making bleaching powder at Niagara Falls in 1898; the Pennsylvania Salt Manufacturing Company at Wyandotte, Mich., started in 1903, followed by Hooker Electrochemical Company in 1906. Various paper manufacturers and other mills added bleach to their own production. The high-water mark for bleaching powder was reached in 1916 when the American production for sale exceeded 133,000 short tons.

In 1891, two years before Le Sueur started, imports into the United States were at their highest, amounting to 55,578 tons. In 1913 they had dropped, on account of domestic production, to 38,000 tons, and in 1924 imports were only 5400 tons. It is interesting to note that the value declared for customs entry purposes in the United States of imports in 1871 averaged $39.60 per short ton. The American price now is $40.00 per short ton with the dollar at a purchasing power of about sixty cents, as compared with the dollar of 1871.

The use of liquid chlorine has grown rapidly within the last few years, and practically all large users of bleach in this country today prefer it to bleaching powder. Manufacturers of pulp and paper consume 65 per cent of the liquid chlorine production; another 22 per cent is used by textile mills and bleacheries; 10 per cent goes into water purification and for sanitation. It is principally

responsible for the freedom of our water supplies from dangerous bacteria. The remaining 3 per cent is consumed in miscellaneous chemical manufactures.

Chlorine manufacture, like so many other chemical processes, cannot be varied at will, as the disposal of both the caustic soda and hydrogen simultaneously produced is necessary to its commercial success. The investment in the industry is relatively high, two dollars of capital being required for each dollar of sales annually.

Explosives. The first safeguard necessary for a country's defense is gunpowder. In 1802 Thomas Jefferson felt that the production of this article needed European support, and induced E. I. du Pont de Nemours to leave France and undertake the construction of works at Wilmington, Del., for this purpose. It is another illustration of the close relationship that has always existed between Europe and America in the development of the chemical industry. The Dupont family have continued for 125 years to identify themselves with this industry. There have been various occasions when the thought of transferring the responsibility to other shoulders was considered, but on each occasion one or the other of the family has shown the courage and persistence to carry on.

Up to about sixty years ago black powder was the universal explosive for both military and commercial purposes, the only difference being that the former contained potassium nitrate and the latter mostly sodium nitrate or Chile saltpeter. But the same equipment served, and a powder mill of the Civil War period could without expense be turned from peace to war work. Organic chemistry, since then, has developed military explosives that are unsuited to works of peace.

Alfred Nobel was the outstanding figure who accomplished this result. A Scandinavian by birth, he visited the United States in 1865 and made arrangements for the manufacture of his new invention of nitroglycerin. Two years afterwards he gave the Giant Powder Company of California the American rights to his dynamite process.

The modern explosives industry may be considered to have five branches differing in character, raw materials, and plant (except that nitrates or nitric acid go into the manufacture of each). They are: (1) black powder; (2) high explosives for blasting;

(3) smokeless powder; (4) high explosives for military purposes; (5) blasting caps and fuse. The second is the largest in point of quantity and value, black powder coming next. While in the early days of this country's history practically all powder produced was used for war or for hunting, these uses now amount under normal conditions to only about three per cent of the total. In 1914 the entire country's capacity for military explosives of all kinds was scarcely more than twenty-five million pounds a year as compared with a production of commercial explosives of about twenty times that amount. During the nineteen months the United States was at war with Germany there were produced for military purposes 273,115,000 lbs. of smokeless powder, 10,796,000 lbs. of military black powder, and 375,656,000 lbs. of high explosives, including picric acid, trinitrotoluene, nitro-starch, and military ammonium nitrate. The consumption of commercial explosives for the year 1926 amounted to 157,686,825 lbs. of black blasting powder and 378,203,353 lbs. of high explosives, or nearly one third more than the amount of military explosives produced during the year of greatest conflict. These figures show clearly that the explosives industry today is above all an industry of peace. The war plants which had to be built for war supplies have been dismantled and the capacity for war explosives is again an insignificant part of the total capacity, while the commercial plants are not adapted for military uses.

Without explosives neither coal nor ore could be mined in sufficient quantity to keep one large steel plant operating. We would not have cement and stone to build highways, factories, or office buildings. The building of tunnels, bridges, dams, drainage and irrigation projects, and other great engineering works would require immensely greater time and labor if, indeed, they were not made entirely impossible, without this assistance. The convenience and luxuries of modern life owe a great debt to explosives.

Our vast present production of explosives has been reached from a very modest production of gunpowder in Massachusetts in the seventeenth century. In the first decade of the nineteenth century this had increased to over two hundred mills scattered over the continent and ranging in output from a few pounds to a maximum of 250,000 lbs. a year. Since then the number of mills has gradually declined, with a corresponding increase in production per unit. The greatest development began after the Civil

War, due, on the one hand, to the introduction of high explosives, and on the other to expansion of mining, railroad building, and other engineering works. Today there are about seventy plants located in twenty-three different states. They are owned by twenty-four corporations, of which twelve confine themselves to black powder, seven to high explosives, and five make both. Three of them also manufacture smokeless powder and four produce blasting caps. In addition there are two companies engaged in the manufacture of fuse. The largest dynamite plant in the country has a capacity of sixty million pounds a year, and the largest black-powder mill can turn out 1,800,000 kegs of 25 lbs. each. It should be pointed out, however, that the total capacity of the country for black powder is more than 100 per cent, and for high explosives more than 50 per cent greater than the actual consumption. This is due to the fact that consumption is seasonal and that the plants must be capable of satisfying the peak demand to avoid storing large quantities of explosives. As there are objections likewise against shipping long distances, such plants are located wherever the demand is sufficient. Thus we find the most important explosives center in New Jersey and Pennsylvania, where engineering projects and coal mines consume large quantities.

The dynamite industry had its birth towards the end of the sixties around the San Francisco district. The Birmingham district in Alabama, with neighboring iron and coal mines, likewise has called for local manufacturing, and a new mill is now in course of erection there. Other powder plants are located in the mining districts of Missouri, Illinois, Utah, Arizona, and other states. American capital is also largely interested in Canada, Mexico, and Chile.

Of the raw materials used by the industry saltpeter alone is found only in small quantities in the United States. This proved very embarrassing during the Revolutionary and Civil Wars and caused grave concern during the World War. In the Civil War, only ten per cent of a total of three million pounds of saltpeter (equivalent to four million pounds gun powder) used by the South was produced from deposits in the limestone caverns of Tennessee, Alabama, Georgia, Arkansas, and Texas, while the rest had to be imported from England and run through the blockade instituted by the North. The development of nitrogen fixation, which makes

it possible to obtain ammonia, nitric acid, and nitrates from air promises to remove this difficulty.

Glycerol is obtained from soap works, and if this should prove insufficient, glycerols can be made from the unsaturated hydrocarbons found in casinghead gas or from by-products of oil-cracking, or glycol, a synthetic ethylene product, may be used. The raw materials for military explosives are likewise found in abundance: linters as a by-product of cotton, or in default of that, chemical wood pulp; benzene, toluene, and xylene in the distillate from by-product coke-ovens; alcohol through fermentation of corn or molasses; acetone from acetate of lime obtained in hardwood distillation or through another type of fermentation of corn. Mercury for fulminates is generally imported.

Although explosives present a certain danger both in manufacture and handling, containing as they do a vast amount of energy which is released by a comparatively slight impulse, the explosives industry is not nearly so dangerous as it is popularly supposed to be. Chemical and physical control, education of the workmen, and the application of proper safety devices have reduced the hazard so that this industry compares favorably in the number of accidents and fatalities, per man employed, with many industries that are not ordinarily considered as unduly hazardous. The education of the consumer and the development of such explosives as the permissibles have also greatly reduced the accident rate in the transportation and use of explosives. The industry owes a debt to the U. S. Bureau of Mines and the Bureau of Explosives of the American Railway Association. In their 1926 annual report it is stated that not a single life was lost in the transportation of explosives over the railroads of Canada and the United States and that the property loss was only $46,000, of which $21,000 was toy and railway torpedoes.

Torpedoes and fireworks are made by a number of mostly small concerns who buy their powder from the explosives companies or in many cases mix their own deflagrating or explosive mixtures.

Celluloid and Plastics. A plastic is a body which during its process of manufacture can be made to soften sufficiently to be poured into molds, pressed into forms, or bent into shape. This is usually accomplished by the aid of heat or pressure, or both. The most important of these, owing their origin to American endeavor, are: vulcanized rubber produced by Charles Goodyear in 1839;

celluloid invented by John Wesley Hyatt in 1869; casein plastics invented by Emery Edwin Childs in 1885; and the bakelite class of phenol-formaldehyde condensation products discovered by Leo Hendrick Baekeland in 1909.

Of these, nitrocellulose products are by far the most generally used. It is the raw material of smokeless powder, and can be converted into celluloid, photographic films, artificial silk, artificial leather, and the modern lacquers. It is prepared by treating cellulose with nitric acid, obtained from the action of sulfuric acid on sodium nitrate and now to a growing degree, synthetically. There are various methods of treating the cotton and various methods of controlling the nitration, but generally three classes of nitrocellulose are called for: artificial leather cottons containing 11.5 per cent to 12 per cent nitrogen; lacquer and film cottons containing around 12 per cent nitrogen; and explosive cottons ranging from smokeless powder containing 12.6 per cent to military gun cottons containing 13.2 per cent nitrogen. The maximum theoretical combined nitrogen content possible is 14.2 per cent, but this compound is too unstable for use.

To change nitrocellulose to other useful forms, it is first made into a paste or thick solution with suitable solvents, ranging from mixtures of alcohol with ether or acetone to mixtures of various special solvents such as esters of ethyl, propyl, butyl, and amyl alcohols with various organic acids. This is necessary before it can be mixed with other essential ingredients. For celluloid manufacture this plastic mass is mixed with camphor or such compounds as triphenyl or tricresyl phosphate so that it can be molded when warm.

Celluloid owes its creation to the offer of a $10,000 prize by an American billiard ball manufacturer for a satisfactory substitute for ivory. This offer came to the attention of John Wesley Hyatt of Albany, who, though no chemist and unfamiliar with the German, French, and English studies in nitrocellulose, distinguished himself by discovering that combining nitrocellulose with camphor produced a plastic material that could be made transparent or opaque and was susceptible to dyes or colors so that a great variety of effects could be produced. Upon this discovery an immense industry has been built in plastics. Celluloid is now carved, planed, turned, sawed, molded, rolled, stamped, or polished as required.

The development of Goodyear's vulcanization process, in which rubber is rendered more generally useful by heating with sulfur, has resulted in an immense industry, consuming quantities of sulfur and numerous chemical products. The advent of the automobile gave the rubber industry so vigorous and continuous a boost that it has not seriously felt the encroachments made by other plastics upon the field of hard rubber.

The production of plastic bodies from milk curds has also developed into an important American industry. The various methods in use for the production of casein plastics are based upon the fact that the casein curd is converted into a tough and insoluble product by treatment with a hardening agent, usually formaldehyde. Casein plastics may be made clear and transparent, translucent or opaque, and like celluloid, of any color and form. Its products are in every hand, in the form of buttons, combs, fountain pens, cigarette holders, etc.

In the course of a very extended, painstaking, and thorough chemical research to find a substitute for shellac, L. H. Baekeland, the inventor of "Velox" photographic paper, found that when phenol (carbolic acid) and formaldehyde (the common disinfectant) are heated together under pressure, in the presence of a very small amount of alkaline substance, he could produce an extremely useful plastic. Upon the conditions under which the reaction was carried out he obtained either a fusible and soluble resin, or one which is both infusible and insoluble, unattacked by the majority of chemical reagents, and a non-conductor of electricity. If the reaction be arrested before completion, it is possible to add pigments and fillers of many kinds to the resinous combinations. The product can then be molded into any shape desired.

The influence of Bakelite on the electrical, radio, and other industries has been enormous. Its consumption has grown to such an extent that the supply of natural phenol (from coal tar and tar oils) no longer suffices, and the Bakelite Company therefore built a large synthetic phenol factory.

Photographic Chemicals. Those who desire to be informed on the fascinating subject of photography cannot do better than study "Fundamental Photography" by Dr. E. K. Mees, Research Director of the Eastman Kodak Company, and "Chemistry of Photography" by Professor R. Meldola. This section can only touch on it as an industry created by the chemist out of an idea

of Thomas Wedgwood in 1802, which was elaborated on by Davy in the Journal of Royal Institution of that year.

The process of recording objects by the action of light has been subsequently built to its present importance by a hundred contributors of which Niepce, Daguerre, Talbot and Herschel, and Maddox and Lumiere are historic founders. George Eastman of Rochester, N. Y., undoubtedly popularized the study. Believing that the process of photography would develop in proportion to its simplicity, he employed the sensitized film, then only a scientific novelty, and developed a suitable camera that anyone could use, and now the works bearing his name turn out more than twice the output of the largest European factory. The scale of operations has called for a complete branch of the chemical industry to supply cheaply the many chemicals necessary, and the great works of Germany and France engaged in this industry are, like Eastman, large chemical manufacturers for their own use and for distribution in the photographic trade. A report issued by the leading organization of the German film industry declares that America governs about 95 per cent of the world market, and in 1925 received about $75,000,000 from the export of film licenses, some 20 per cent of which came from Germany.

Six hundred million feet of films for moving pictures are produced annually at the Rochester factory, and require acetic anhydride, nitric acid, camphor, alcohol, amyl acetate, and other chemicals finally sensitized with more silver than is used annually for the nation's entire coinage.

The films now used in photography are made in very much the same manner as celluloid with the exception that the mixture of nitrocellulose and camphor is diluted to a thin solution with a mixture of solvents, and then dried continuously on a revolving drum in a thin film.

The development and fixing of the negative and the ultimate perfection of the photograph call for sulfite or hyposulfite of soda, hydroquinone, metol, ortol, pyrocatechin, glycin, various bromides, chromates, iodides, citric acid, hydrochloric acid, acetic acid, and many other chemicals in smaller quantities.

Rayon. If nitrocellulose, dissolved in a suitably volatile solvent, be forced through a nozzle known as a spinneret with many minute orifices, a fiber resembling silk is obtained after thorough washing and drying. This fiber is highly inflammable, but rendered safe

to use by denitration with suitable caustic solutions and more washing and drying, when it is ready to enter into commerce as one of the several kinds of artificial silk or rayon. Another rayon is prepared by the use of cellulose acetate instead of nitrate. It is waterproof and has somewhat different properties, although similar in appearance and utility. A third variety, prepared from cellulose by the so-called " viscose " process, is manufactured in much the largest quantities and has still another set of characteristics which make it useful for combining with wool and cotton and for many of the purposes of raw silk. Recently the so-called Bemburg or cuprammonium process has been put into operation, utilizing the solvent effect of ammoniacal solutions of copper on cellulose to form it into a silky fiber. None of these rayons is identical with silk, but the fiber is so beautiful that for many uses it serves the same purpose, especially as it is much cheaper. While none of these processes is of American origin, their practice in this country has grown to the extent of producing 51,800,000 pounds of rayon valued at $88,000,000 in 1925. Twelve plants were operated during that year, using wood pulp and cotton linters as the raw materials.

The development of rayon has brought about many interesting changes in our industrial organization. During the War the crushers of cotton seed for the recovery of oil did everything in their power to recover the last traces of cotton fiber for use in making smokeless powder. The scarcity and high value of cotton linters for this purpose justified large investments in machinery for their recovery, but at the close of the War the drop in price of the product rendered this investment quite unprofitable. Consequently, steps were taken to find uses for linters in peace which would be able to pay some return on the money tied up in these plants. The first solution offered was the manufacture of paper, but the growing demand for linters for rayon manufacture, then just beginning, soon reached a point of using not only all that could be produced, but also even greater quantities of paper pulp.

The raw materials required for the manufacture of rayon differ according to the process employed. Cellulose as it exists in cotton linters, or wood pulp, is required by all manufacturers, but the method of its conversion differs greatly. The older nitro-cellulose process requires nitric and sulfuric acids, caustic soda, and solvents such as alcohol and ether, and preferably uses cotton linters as a

source of cellulose. The acetate process requires sulfuric acid, acetic acid, and acetic anhydride, acetone, and alcohol acting on the cotton linters. The viscose process uses chiefly wood pulp, which is treated with a dilute solution of caustic soda to form soda cellulose, which is converted into viscose by the addition of carbon bisulfide. Many operations follow before extrusion, after which it is hardened into fibers by very dilute sulfuric acid. The cuprammonium process consumes cellulose, copper sulfate, ammonia, and sulfuric acid in its preparation, and finally, like viscose silk, emerges a pure cellulose fiber.

Each of these processes produces a silken fiber different from silk, although each has the characteristic, luster, and qualities of silk. The dyeing properties differ, the variation in this respect being utilized to produce alluring effects in dyeing and finishing.

Artificial Leather. Solutions of nitrocellulose, suitably colored and containing what is called a plasticizer to prevent the hardening of the nitrocellulose, are used to give a leather-like finish to fabric or paper. The plasticizer most used to prevent brittleness in the finished material is castor oil, which renders the film tough and flexible. Various colors may be imparted to the material by dissolving a suitable dye in the solution, and any desired grain may be imprinted upon it. For book binding this imitation is more satisfactory for use than leather as it is not so subject to destruction by insects or by time. For upholstery purposes, its cheapness particularly recommends it, and immense quantities of it are used annually for these purposes.

Lacquers. In 1923 the first innovation in the art of painting since the introduction of drying oils in the sixth century, was heralded by the use of nitrocellulose solutions to replace varnishes and oils in paints. Some small use of lacquers of the kind had been previously made, but it was only then that a method was found of preparing a nitrocellulose solution which contained enough cellulose body to cover a surface properly and yet not too thick to apply. Proper preparation of the nitrocellulose, a choice of solvents to give a gradual evaporation from the surface, and the addition of certain natural resins, such as dammar, to form part of the finished coating, yield a solution into which pigments can be ground to form highly wear-resistant paints having the property of drying within a few minutes. Ordinary oil paints and varnishes require many hours to dry between coats, but by using

the new lacquers a completely finished automobile with six or seven pigment and finishing coats can be done in a day and be more durable than formerly when six weeks were required.

This entirely American development has seriously affected the paint industry by offering competition in an unsuspected form, and has brought about the commercial creation of numerous solvents heretofore only laboratory curiosities.

Alcohol is used in quantities, but its solvent properties are not wholly satisfactory. The petroleum refiners were called upon to supply iso-propyl and other unusual alcohols made from the waste gases of their cracking stills. Butanol, another member of the alcohol family, gave very satisfactory results and was soon called for in great quantities.

The fermentation of corn starch to supply acetone for airplanes had during the War developed a new process in England and Germany, and out of this grew the Commercial Solvents Corporation. The later demand for butyl alcohol simultaneously produced made acetone of much less importance. Great trouble was for some time experienced in controlling the ferments, as their contamination with the wrong bacteria worked havoc with the process. This company overcame these troubles and doubled its output three times during the intervening four years of growth of the lacquer industry. The phenomenal demands of this lusty infant industry have incited the interests of chemists in the chemical elaboration of petroleum, and two plants of importance have been built to manufacture solvent alcohols until recently commercially unknown. Nothing that might possibly yield a solvent is being neglected in the search for raw materials for lacquer manufacture.

Values involved in this single development, swift though it has been, beggar by comparison the total values of chemical manufacture of a few decades ago. It is too soon to attempt detailed statistics, — which would have no value for more than a very short interval, — but already the monthly turnover is well above the million dollar-mark, and constantly increasing. In 1925, sixty-seven plants produced 4,880,000 lbs. of lacquers. In 1926 the number of plants had increased to 111 and production had swelled to 10,136,800 lbs., an increase of 108 per cent in one year.

Alcohol. The ordinary person associates alcohol with endless discussions in regard to its intoxicating properties when used as a beverage, but it is none the less essential in its chemical properties

for many manufacturing operations. The Federal Government, following the Civil War, largely increased the tax on beverage spirits to help its revenue, but did not recognize its use in manufacturing.

In 1906 Congress passed the first real denatured, or industrial tax-free, alcohol act. To quote statistics, approximately 2,000,000 wine gallons of denatured tax-free alcohol were consumed in manufacturing during the first year of the act. During the war year of 1917, 55,000,000 gallons were used; by 1919 approximately 35,000,000 gallons were used. Today more denatured alcohol is used than pure alcohol, the greater part coming from factories that never supplied spirits for home consumption. The Volstead Act for the first time gave a clear legislative distinction between the two points of view, fixing the status of alcohol in manufacturing, and rendering possible the great future developments of the industries dependent on it.

The modern rectifying or alcohol still was practically unknown until 1870 and was not a producing factor. There was a crude rectifying industry which collected "pot-still" distillates, leaching them through charcoal to remove fusel oils after treatment with lime or soda, and then redistilling. As rectifying column stills came into more general use, the distillate increased in alcoholic strength and the impurities became by-products of definite value. Alcohol, or ethyl alcohol, is the universal organic solvent and is, in addition, the sole available commercial source of the ethyl group, which chemists may interchange to form other substances as required, to realize modern organic chemical synthesis.

Germany first recognized the essential importance of an abundant and cheap supply of rectified alcohol to the organic chemical industry. The phenomenal development of her dye and medicinal operations put her in a commanding position, and the government heartily encouraged alcohol production and its subsequent manufacturing use, foreseeing that her military and economic defense required it.

Until recently, American development was slow, alcohol being supplied chiefly from distilleries accustomed only to consider its medicinal and beverage value. Its manufacture was the particular business of the whisky distillery, and the personnel did not include chemists familiar with the progress science was making in nitrocellulose, plastics, lacquers, and varnishes. The ethyl, butyl, and

amyl acetates were known only on the laboratory shelf and were not of any industrial importance.

The War created such a demand for both alcohol and these new chemicals that far more capital flowed into the industry than was likely to compensate the investor when war ceased. The certainty of an over-production became so apparent by 1916 that the directors of the largest producing company determined to engage creative talent capable of developing new consuming outlets. Dr. M. C. Whitaker, known to thousands of students and chemists as the organizer of Columbia University's Department of Chemical Engineering, was selected. Dr. Whitaker's previous industrial and business experience fitted him to face the serious problems. A practical means of producing absolute alcohol by distilling with benzene was developed under his direction and has put America in the forefront in this product. This has made possible the production of many esters and essential oils not previously economically practicable. It is now one of the big branches of the chemical industry, with a turn-over in the neighborhood of $75,000,000 or $80,000,000 per annum.

The center of gravity, so to speak, of the alcohol industry had in consequence of these developments moved from the grain belt in the Middle West to the seaboard, where the cheaper raw material, molasses, could be obtained direct from tank steamers. Industrial alcohol is now chiefly made from black-strap molasses, just as rum is, and depends upon the sugar crop. If a large amount of sugar has been planted, a large amount of molasses is recovered. If a Cuban or West Indian planter has been discouraged with an over-production, then he works with old sugar cane, which yields very much less molasses, and the price automatically goes up.

The Dupont Company very soon saw the opportunity, and as a large consumer of alcohol, joined forces with an important grain-alcohol group, building works at Deepwater, N. J., near their great dye and explosive works. Smokeless-powder production and some of the various war gases, notably mustard gas, depend absolutely on ethyl alcohol. In other words, every alcohol plant is necessary to the arsenal.

Alcohol is also attaining a definite position among motor fuels for its value in improving the combustion of gasoline in motors. The subject is of greater importance to Europe, where elaborate demonstrations are in progress, but the same economic principles

are involved, and those concerned with these important studies are alert and ready to act at the proper time.

It is unfortunate that the social reformer in the pursuit of prohibition should permit his prejudices to retard these developments by seeking to load on this industry much of the expense of enforcing an extreme act that is the cause of unnecessary discontent and trouble.

While the alcohol distiller has substituted molasses for corn as a raw material, other processes now employ corn to an astounding degree, as in the manufacture of dextrine, glucose, and the recent development of butyl alcohol. A small quiescent operation built to supply acetone for war purposes by the fermentation of corn starch offered the opportunity, as the butanol, obtained as a by-product, proved to be a ready base for further valuable solvents. The modern lacquer now universally used for painting automobiles, particularly, has forced the growth of this endeavor, and at present the first and largest operators consume several million bushels of corn per month in the manufacture of these solvents.

In addition to this growing industry, methanol, prepared from water gas, ethylene derivatives from acetylene and natural gas, and other alcohols from casinghead gasoline and petroleum are becoming increasingly important. These operations dwarf by comparison the largest units of chemical industry as they existed two decades ago in spite of the fact that the oldest of them has scarcely had ten years to establish itself.

Wood Chemicals. The manufacture of charcoal from wood was practiced early in the American Colonies, but it was not until 1830 that the recovery of the by-products of the process was begun by James Ward at North Adams, Mass. The distillation of hard wood yields not only charcoal but also methanol (wood alcohol), acetic acids, acetone, pyroligneous acid, and wood tars. The first three of these are valuable solvents and are in great demand today for use in the preparation of lacquers. Methanol is largely used as a denaturant for ethyl or grain alcohol and to a less extent (on account of its higher prices) for solvent purposes. It is now being made synthetically from water gas in quantities both here and abroad. Acetic acid is largely required in the manufacture of white lead and for numerous organic compounds, where it is used as a solvent. It is now being synthesized, using acetylene as a raw material. Acetone, the third wood product, is less important but

finds use in various solvents. The investment in the hardwood distillation industry in the United States was approximately $100,000,000, but the process already referred to and the synthesis of its principal products threaten its extinction.

Pine is distilled in great quantities for making wood turpentine, a valuable solvent in the paint and varnish industry and in rosins. Pine oils, similarly made by distillation, are used in the flotation process of ore concentration.

Coal Tar Industry. Coal tar has evoked the notion of fragrant synthetic perfumes and rainbow colors arising from evil-smelling and sticky waste of gas works. As the quantity increased it became such a nuisance that a new branch of chemical industry in the United States came about in a rather commonplace way. The economic utilization of coal tar, therefore, by force of circumstance, followed about thirty years after the introduction of gas lighting in the larger cities.

Refining coal tar has made few American multi-millionaires. Compared with petroleum refining, which, from a technical standpoint, runs nearly parallel to it, its rate of growth and present volume is insignificant.

Gas-lighting corporations were formed in Philadelphia, Washington, Baltimore, and a few other cities about 1816. By-product coke ovens were then unknown, and the gas works supplied all the tar. The Warren family, whose name and descendants are still associated with tar products in roofing and road building, were probably the first to distill coal tar, about 1850, erecting plants at Cincinnati and Buffalo.

Tar paper and pitch for built-up roofing were the principal products of tar distillers for many years, and the numerous well-authenticated records of satisfactory service for forty or fifty years attest their merit.

Creosote oil came later. Since the beginning of the wood-preserving industry in the United States, about 1870, it has been an important product of tar distillation.

The beehive oven originally used for coal distillation wasted all of the by-products, but it produced a hard coke well suited to carry the load in the blast furnace, whereas the by-product oven in its early career did not produce so consistently satisfactory coke. Its appearance also was different, and this added to the conservatism and prejudice that had to be overcome. In time, however,

the by-product oven mastered the problem of fuel selection to supply yield and quality of gas and a hard coke. In 1913 the proportions of beehive and by-product coke oven produced in the United States were 72.5 and 27.5. In 1925 the figures were more than reversed, standing 21.4 and 78.6, respectively.

The production of coal tar in the United States during the last quarter century shows an enormous growth:

In 1901 — 60,000,000 gallons
In 1925 — 525,000,000 gallons

The by-product coke oven is by far the most important source of coal tar. The two other sources, the horizontal and vertical retort for city gas, produce together hardly more than 10 per cent of the total.

About 85 per cent of the by-product coke ovens are primarily producers of metallurgical coke; hence the great tar producers of the country are the steel companies. The outstanding producer, the United States Steel Corporation, produced 147,000,000 gallons of coal tar in 1925 or over 30 per cent of the total by-product coke-oven tar of the United States.

The principal products of coal-tar distillation in the United States (including only derived products and not addition products in which a coal-tar derivative is a component) are in round numbers:

	Estimated Volume	*Estimated Value*
Road Tar	80,000,000 gallons	$8,000,000
Creosote and other Tar Oils	50,000,000 gallons	7,000,000
Pitch	250,000 tons	3,000,000
Naphthalene	17,000 tons	1,000,000
Tar Acids (Phenol and Cresols)	4,500 tons	900,000
Benzol and Homologs	1,500,000 gallons	350,000

The relationship between the coal-tar dye industry and coal-tar products requires definition: At present the only coal-tar derivative which is indispensable to the dye industry is naphthalene. Benzol, toluol, and xylol are extracted from coke-oven gas, and the quantity from tar is negligible.

Few coal-tar products are really indispensable, but no satisfactory substitutes have yet been found for cresylic acid used for disinfectants as well as synthetic plastics such as bakelite; creosote oil, for wood preservation; naphthalene, as a raw material for dyes; and pitch, as a high fixed carbon binder in the manufacture

of electric carbons and in foundry facing compounds. This country cannot produce sufficient creosote oil or cresylic acid from the tar distilled, and these commodities are still imported in quantity, otherwise there would be a large overproduction of pitch.

Unfortunately all the residual products of coal-tar distillation, including road tars and water-proofing pitches used for roofing and protective coatings, are in competition with petroleum products. Until a better balanced demand exists between these residuals and the distillates, many localities will find it profitable to continue the use of tar for its fuel value, which is higher than that of coal and approximately equal to fuel oils.

During the past decade the by-product coke industry has steadily increased in economic importance until it has become not only an integral part of our great steel and gas industries, but a basic industry in itself, around which large chemical plants are being built. In 1926 the by-product plants of the United States had a potential carbonizing capacity of approximately 72,000,000 tons of coal per year, producing annually about 44,000,000 tons of coke, 535,000,000 gallons of tar, 700,000 tons of ammonium sulfate, 165,000,000 gallons of crude benzol, and 700 billion cubic feet of gas.

Marked progress has been made in the by-product coking art within recent years and the process has been improved greatly as regards carbonizing capacity and thermal efficiency of the oven itself. Several different types of by-product coke ovens are in use in this country, those best known being:

(1) The Koppers-Becker Oven
(2) The Wilputte Oven
(3) The Semet-Solvay Oven
(4) The American Oven
(5) The Roberts Oven

Dyes. America now makes about 95 per cent of the coal tar or aniline dyes it consumes, and exports large quantities. Preliminary figures compiled by the United States Tariff Commission show a domestic production of coal-tar dyes for the calendar year 1926 of about 88,000,000 lbs., with a value of about $37,000,000. The production of the newer vat dyes established a new record in 1926, with a total of over 4,000,000 lbs. as compared with 2,600,000 lbs. in 1925. Few aniline dyes were made in the

United States prior to the World War. Germany produced about \$68,000,000 worth of dyes out of a world production in 1912 of \$90,000,000. The average price of exported dyes from Germany in 1912 amounted to 21.53 cents per pound. The average price of all domestic dyes sold in 1926 was 42 cents per pound; indigo, the most largely used, selling in 1926 at an average price of 12.8 cents per pound, which is considerably below its pre-war price.

The situation, however, in America until the War was most disheartening because the subject was not understood and there was actual opposition of dye-consuming trades and indifference of financier and the public. It was fortunate indeed when war was declared that there was a nucleus upon which a comprehensive dye industry might be established. Their manufacture had first been attempted in Albany in 1866, when the chemistry of these products was in its inception. England, Germany, and the United States all received their stimulus through the same source. August William Hofmann, a German, born in 1818, became so renowned in the research of carbon compounds that he was selected in 1845 by the Prince Consort to assume the directorship of the new Royal College of Chemistry in London. An English student, William H. Perkin, entered this college in 1853, and was selected by Dr. Hofmann to become his assistant. In 1856, while attempting to make artificial quinine, he was fortunate enough to produce what proved to be a dye now known as mauve, the first aniline dye in history. Dr. Hofmann returned to Germany some years later and successfully continued the developments originated at the Royal College.

About this time Arthur Bott, a German paper maker, residing near Albany, N. Y., went abroad and while there met Dr. Hofmann, who so interested him in the subject that he concluded to start dye making in the United States. The Albany Aniline Chemical Works was accordingly organized in 1866 with a fifty-year charter. Aniline red, magenta, and Hofmann's violet were all produced, but the products were not entirely satisfactory, as the technical organization was inadequate. Mr. Bott, in 1871, returned to paper making. James Hendrick, a stockholder, was elected president in his place, and reorganized the works, arranging with Bayer and Company, then a small concern at Barmen, to send over experts to make aniline red, while importing the raw materials, aniline and arsenic acid. Success followed this move, and the

Albany Chemical Works became ambitious to be independent of imports. The industry was in its infancy, and they made good progress for that period.

In 1881 Ellwood Hendrick, son of the president, having completed his chemical studies in Germany, took charge of the corporation's chemical development. The works were enlarged and various chemists engaged for the manufacture of the many necessary intermediates and finished dyes.

In this same period a tanner in Buffalo named Jacob Schoellkopf, a naturalized American, sent his eldest son, Jacob F. Schoellkopf, to Heidelburg University. Upon his return, in 1878, Schoellkopf, with his father's backing, built a small plant for aniline dyes, but from the outset they too received little encouragement. Fortunately the Schoellkopfs were blessed with ample funds and German tenacity, and the works they inaugurated were consistently operated, and are at present the largest in the country.

One other effort should be recorded in connection with the manufacture of ultramarine — dyes differing from aniline, *i.e.*, a blue pigment which was manufactured by Heller and Merz of Newark, N. J.. They too found little to encourage them, but the Franco-Prussian War of 1870 brought emergency orders which probably enabled these early producers to perpetuate their name. One by one further products have been added to their list — magenta, eosines, nigrosines, orange, chrysoidine, Bismarck brown, and other dyes, for all of which a limited sale had been found.

The opposition was built on the fact that the textile manufacturers wanted protection for themselves, but insisted that dyes were their raw material and therefore should be free of duty. In 1883 they succeeded in persuading Congress to pass an Act which so reduced the tariff that the manufacture of aniline intermediates and most of the dyes nearly ceased for more than thirty years.

The German dye industry had meantime grown to be a world power, the vast majority of goods in the world being dependent on German works to give them marketable effects and colors. The outlook would indeed have been disheartening had not the General Chemical Company, the Barrett Company, and the Solvay Process Company in 1911 organized the Benzol Products Company to make nitrobenzene, aniline oil, and other intermediate chemicals which form the basis of these dyes. During the thirty years intervening such attempts had been made several times in America, with

financial loss, but this new effort offered all of the heavy chemicals necessary at cost, together with the full-hearted backing of their great organizations and capital to operate, if necessary, without profit. Even that brought little American support and bitter German opposition. Then came the War.

Its effect upon America, as reported in March, 1916, by the German Consul, General Hossenfelder, can best be quoted: "Through the lack of dyestuffs alone not only is a whole list of important industries (wool, cotton, leather, paper industry, etc.) gradually made lame, but for the great public living becomes more expensive both through the rise in price as well as through the small durability of all products for whose production colors are used. We are unquestionably face to face with conditions which are without a parallel in the past."

Germany's refusal before America entered the War to permit her dyes to be shipped freely to this country proved to be the greatest possible stimulus to this branch of the chemical industry of the United States. Instead of bringing about the ruin of textile and other industries through the lack of dyes and foreign-made chemicals, an entirely unexpected impetus was given. The acute shortage in dyes made it possible to dispose of products of a quality ordinarily unacceptable at prices never dreamed of. This condition enabled manufacturers to carry on experimentation with a reasonable assurance of a profitable outlet for the results of their attempts.

The attention of the Alien Property Custodian was called to the situation and to the extraordinary embarrassment that would ensue, were the enemy patents in his possession permitted to pass into hands where they might again be employed for intimidation and repression. The idea was conceived that if these German chemical patents could be placed in the hands of an American institution strong enough to protect them, a real obstacle might be imposed after the War to a renewed attempt of a German monopoly and at the same time the American industry freed from the prohibition enforced by patents. Accordingly, these considerations were laid before the American Dyes Institute, the Manufacturing Chemists Association, and others interested. The suggestion met with unanimous approval, and as a result a corporation was organized for the purpose and called The Chemical Foundation, Inc.

The first president of The Chemical Foundation, Francis P. Garvan, showed clear vision and courage equal to the extraordinary strain subsequently imposed upon him. The President of the United States on February 13, 1920, made an executive order which has since by the courts ratified the transactions, and pursuant to that order, the custodian confirmed the assignments theretofore made to The Foundation of over four thousand patents.

The Chemical Foundation must be credited with the successful fostering of this part of the chemical industry, for notwithstanding the earlier labor and energy contributed to its vitality the impartial facts submitted by The Chemical Foundation and its wholehearted support have been essential to the formation and maintenance of a well-rounded chemical industry.

Calcium Carbide, Acetylene, Oxygen, Nitrogen, Argon, Neon, Helium, Ethylene (Calorene), the Oxyacetylene Welding and Cutting Processes. Romance in industry is exemplified in the history of calcium carbide and the developments that have come from the epochal discovery of Thomas L. Willson and associates at Spray, N. C., in May, 1892. Willson, seeking to produce aluminum in a Heroult electric furnace, had tried various combinations of materials with bauxite, without success. He finally conceived the idea that if metallic calcium were made first, it could be used as a reducing agent to free the aluminum from the ore, and thereupon charged his furnace with coal tar and lime. Again he was disappointed in the product. Instead of calcium or anything resembling it, he found a mass of gray, rocklike substance of no apparent commercial value. However, it was found to slake in water and give off a combustible gas — a gas of peculiar odor which burned in the air with a smoky, red flame.

Analysis by Dr. Venable of the University of North Carolina, showed the substance to be calcium carbide, and the gas, acetylene. Thus was discovered a commercial method of producing calcium carbide, first made by Wöhler in 1862, and acetylene, discovered by Davy in 1837. Calcium carbide made small gas plants feasible for lighting; it is a source of numerous valuable chemicals, and the basis of the great oxyacetylene processes that are revolutionizing methods of joining and fabricating metals.

Inasmuch as calcium carbide, sealed in air-tight drums, can be conveniently and safely transported, and used anywhere for making acetylene by the simple process of slaking in water, and the gas,

when burned in suitable fixtures, produces an intensely white light, it was first promoted for lighting houses, bicycles, trucks, and later for tents, construction jobs, wrecking cars, quarries, mines, lighthouses, and highway signals. Scores of companies sprang into existence for the manufacture and sale of acetylene-lighting generators and equipment. Accidents resulted from faulty designs and applications, and for some years acetylene was under a ban because of its supposedly intractable dangerous characteristics. Through associations formed to promote standard practice and eliminate hazards, the industry has been placed on a sound commercial basis.

Acetylene is endothermic and in unstable equilibrium due to the heat absorbed in its production. For the usual conditions of use or transport, it should not be compressed in excess of 15 lbs. per square inch. If compressed into cylinders filled with a porous substance, eliminating large voids, it is comparatively safe at pressures up to 270 lbs. per square inch. This expedient alone would not satisfy the needs of commerce, however, because the volume of gas compressed at this pressure into a cylinder of size and weight conveniently handled is so small that the freight charges on the package would be quite disproportionate to the weight of the contained gas. Georges Claude and others interested in the commercial development of acetylene, discovered that acetone has remarkable solvent power for acetylene, increasing with the pressure. Acetone dissolves from twenty-four to twenty-five times its volume at atmospheric pressure and proportionately more for each additional atmosphere. Hence, it is possible to compress and dissolve about 275 cubic feet of free acetylene into a container weighing 180 lbs., when packed with a porous filler saturated with acetone, without exceeding pressure of 250 lbs. per square inch.

In 1892 LeChatelier read a paper before the French Academy of Science in which he discussed the remarkable results obtained by burning acetylene in an atmosphere of pure oxygen, using a modified Bunsen burner. LeChatelier estimated that the temperature of the flame thus produced was 3500 degrees C. (6300 degrees F.) or 1000 degrees C. higher than the oxyhydrogen flame, which up to that time was the hottest combustion flame known.

In 1900–01 Fouche and Picard in Paris developed the first oxyacetylene blowpipes, or torches, for welding, using dissolved

acetylene and compressed oxygen. Steel, cast iron, brass, bronze, aluminum, and practically all the common commercial metals and alloys were welded with the Fouche torches. The principle of this new form of welding is melting the edges of the adjacent pieces and flowing the metal together, with or without additional metal fused from a welding rod.

About this time Jottrand, and also Henes, applied the principle of the well-known laboratory demonstration of burning steel with oxygen, noted by Lavoisier more than one hundred years ago, by attaching an auxiliary tube to the torch through which an oxygen jet was directed against steel heated by the oxyacetylene flame. The oxygen burned the metal away beneath the jet, producing a cutting action comparable to that made with a metal saw.

Thus, the stage was set from 1900 to 1910 for oxyacetylene welding and cutting development, but one of the principal actors in the drama — oxygen — could be obtained only with difficulty and at high cost. Calcium carbide for making acetylene could be made at a reasonable price where low-cost power, coke, and limestone were available, but oxygen, one of the most abundant elements in nature, was produced in the purity required only by crude and costly chemical processes. Barium dioxide, potassium chlorate, and other chemicals were tried, these methods giving way to water electrolysis, and finally air liquefaction.

The research that culminated in the liquefaction of the air in 1898 unlocked the vast store of atmospheric gases and made oxygen available in any quantity required at low cost. Distillation of liquid air separates the nitrogen and oxygen, producing oxygen by both the Linde and Claude processes 99.5 per cent pure. High-purity oxygen is necessary for the efficient cutting of steel. Nitrogen for nitrates and lamp manufacture, argon for lamps, neon for sign lighting, also helium from the air, have been made available, largely as a result of the discovery of calcium carbide.

Both acetylene and ethylene serve further as raw materials in the field of organic chemicals. Acetylene is transformed into aldehydes, aldols, synthetic acetic acid, carbon black, cuprene, carbene, etc., whereas ethylene is being applied as an anæsthetic and as a ripener of citrus fruits and certain vegetables; its esters are in growing demand as solvents for lacquer products, and the ethylene glycol made from it is furnishing nitro-derivatives for explosives and is being used in considerable quantities as a

substitute for glycerin in anti-freeze mixtures for automobile radiators.

Low-cost oxygen, produced by the liquefaction process, has opened a field for the use of liquid oxygen as an explosive in large open mines, extensive stripping operations, and quarries. Cartridges filled with finely divided carbon, soaked in liquid oxygen, develop about two and one half times the power of black powder and one and one half times that of 40 per cent gelatin dynamite, when detonated.

The history of oxyacetylene is international. Willson, a Canadian, made calcium carbide a commercial product. LeChatelier, a Frenchman, discovered the high temperature oxyacetylene flame. Jottrand, a Belgian, and Henes a German, applied the oxygen-cutting principle. Linde, a German, and Claude, a Frenchman, developed the air liquefaction and rectification process that makes the atmosphere a veritable mine of valuable gases.

The production of oxygen in the United States reported by the Department of Commerce in 1914 was 104,714,000 cubic feet, all processes. The annual production reported for 1925 was over 2,000,000,000 cubic feet. The production of acetylene in 1914 was 121,696,000 cubic feet and the production in 1925 was 525,746,000 cubic feet. The production of hydrogen in 1914 was 1,669,000 cubic feet and in 1925 the production was 150,502,000 cubic feet.

Medicinal Chemicals. The manufacture of those chemical products used in medicine has long been practiced in the United States by such firms as Powers-Weightman-Rosengarten Company, E. R. Squibb and Sons, Merck and Company, Parke, Davis and Company, H. K. Mulford and Company, Eli Lilly and Company, and numerous others. Their products have loomed large in the healing art, and have formed an essentially important division of the chemical industry, presenting problems not so much in mass production as in the painstaking care required for purifying multitudes of materials in comparatively small quantities. The compounds of bismuth, mercury, bromine, and others used in medicine; the alkaloids and other drugs recovered from natural roots, barks, and herbs; and more recently an increasingly large and important number of biological preparations, such as sera, vaccines, and glandular products of various kinds, have all required, in their manufacture, a particular type of chemical skill to assure the physician the absolute identity and high purity of the remedial

agents at his disposal. More recently, following the discoveries of Koch in Germany, there has been developed abroad a new type of medicinal chemical industry based upon the specific action against disease of particular complex organic derivatives of coal tar similar in some respects to the synthetic dyes. Lately this has been transplanted with the synthetic dye industry to the United States with success, and numerous manufacturers, notably the Abbott Laboratories, the Calco Chemical Company, the Grasselli Chemical Company, the National Aniline and Chemical Company, and others are contributing to our national independence in this important type of manufacture. A survey of the chemical industry in the United States would not be complete without considering the development of chemical manufacture in the Mississippi Valley, and particularly the growth and development of Monsanto Chemical Works, St. Louis, Mo. Pioneers in research and in developing new processes, particularly coal tar products, Monsanto was the first in America to manufacture saccharine, coumarin and acetphenetidin (phenacetin). Her part in the commercial manufacture and sale of liquid chlorine was also an important one. In fact, the steady and consistent growth of this one concern was to a large extent responsible for a westward shift of interest in chemistry.

The growing tendency in recent years of pharmacies to become departmental drug stores and then find themselves forced to combine into powerful groups in order to compete successfully, has led to a distinctly new phase in the manufacture of chemical medicinals. Having gathered into great chains primarily for purchasing, the modern departmental pharmacies have drifted into the manufactures of many of their own products which are sold under their own brands. And this has seriously affected the situation with respect to those "old line" houses who for years have well performed their more complex tasks of satisfying the physician in his aim to keep up with progress and prescribe medicines of scientific standards rather than trusting to the much-advertised brands of the corner druggist. The effect of such competition in this field must, however, ultimately result in a higher quality and more varied products, as that is far more important in the minds of physicians and invalids than mere prices.

Important though this branch of chemical industry is, it stands in the peculiar position of being the smaller part — yet that part

with which the general public has the most direct contact, for under ordinary circumstances the average person buys few products of chemical industry direct. The druggist, however, represents, by his sales of small quantities of highly refined chemical products, the skill and specialization of the entire chemical industry to the world at large.

Government Agencies. The Department of Commerce, March, 1926, published a list of thirty-five commercial, industrial, and scientific research organizations belonging to the Chemical Industry without reference to governmental or educational institutions. More than one third of these is supported by chemists themselves; the others by the manufacturers. They afford a very satisfactory opportunity for discussing open questions of policy, progress, and general trade conditions.

This chapter would be incomplete were reference not made to the increasing coöperation of the Department of Commerce. Its Bureau of Standards is one of the most indispensable divisions of our Government. As administered it is a mechanical judge of all measurements. George Washington expressed its motive, saying: "Let us raise a standard to which the wise and the honest can repair." It aims to improve all that affects the measured control of manufacturing and utilization, to fix standards from the billionth of an inch to a nautical degree. It can determine even the heat of the stars, or sound the depths of the ocean. In the same department, The Bureau of Mines and the Bureau of Chemistry both carry on effective work, generously promoting public interest. The statistics of the Bureau of Foreign and Domestic Commerce are unequaled and evoke the admiration of foreign countries. The same may be said of the Tariff Commission.

It is open to question, however, if the Government, when it departs from the broad field of public welfare and control, exerts an economic or beneficial influence. The temptation to undertake chemical manufacturing problems in Government laboratories tends to diminish the responsibility of the manufacturers themselves and involves the Government in large expenditures that should properly be part of the equipment of every well-organized works. Such work by the Government has seldom in the past proved fruitful or profitable. Rather it detracts from the office of Government and in permitting the issue of patents to Government employees destroys the very conception of the patent act.

Patents play a more important part in chemical activities than is the case in other fields. This is particularly true in the newer chemical industries; so patents have always been in the foreground in the consideration of chemical problems. By its very nature, chemistry is in a particularly fortunate position to seek the aid of the patent laws. If a new reaction is discovered or a new product made for the first time, it is difficult either for the patent office or the courts to decide that such a step does not constitute that element of fortune or genius called "invention." And while there have been many bitter contests on chemical matters, from the days of the Tilghman patent on making glycerine and fatty acids by the use of steam under pressure until the recent decisions on the underlying patents covering "Bakelite," chemical patents have largely been sustained.

But the inability to visualize a chemical reaction from a printed description does involve a danger of improper use of the patent laws. At the time of the formation of The Chemical Foundation there was much talk of patents being obtained without the essential directions that would explain the process. There was fear also of the tendency of the larger organizations with their salaried patent departments to cover every possible step without reference to the novelty of the contribution. But these are matters which the court decisions could readily correct should they become serious, and with the spread of chemical knowledge and understanding through the country, there is every indication that the patent laws will be administered so as to give a just and proper stimulus to those who are steadily advancing our knowledge in this field.

Labor Problems. In few industries does labor form so relatively small an item of cost as it does in chemical manufacture. The primary nature of its operations and its office of converting natural raw materials to forms useful for other industries require the work to be carried out on an immense scale which cannot be attained by hand. To carry on large operations successfully, details must be reduced to mechanical routine, and the chief burden of labor involved must be borne by power machines instead of fallible men. There are few operations in chemical manufacture which are hand work in the sense that shoe-making is, for the nature of the changes involved precludes any similarity. Rather the fundamental requirement is to produce conditions under which the

desired chemical reaction will occur in accordance with definite and unalterable natural laws.

In this situation one finds two distinct and different types of individuals in a chemical works — highly skilled chemists and engineers, who study chemical reactions and develop methods for their control and design apparatus that will carry out in the simplest manner the various operations. The workmen in charge seldom have burdensome tasks to perform, as their duties consist most largely of supervision of processes. Both the technicians and laborers are on the whole compensated generously for their contributions to works' operations, and there is little reason for strikes and labor difficulties. Perhaps, too, the close touch necessarily maintained between plant executives, superintendents, and foremen as well as the relatively small squad of men under their charge, has been of essential moment in preventing misunderstandings. The foreman looks to his superiors for constant instruction in his duties just as the workmen look to him. There can be no feeling of " absentee landlord rule " in chemical plant operations, for it would be quite impossible to construct a plant to operate without a great deal of immediate supervision beyond that expected from laborers and their foremen.

Higher wages, paid for the presumed purpose of offsetting certain hazards to life and health, serve with other advantages to promote contentment of labor, and their payment is made possible by the fact that the cost of labor forms a relatively small proportion of chemical manufacturing costs when compared with the items of power and raw materials. The hazard to labor's health has been so reduced by modern engineering methods and design that recent reports of insurance companies show that accident frequencies and severities for chemical industries compare favorably with rates in industry generally.

Beyond the statement that strikes are almost unknown, it is impossible to generalize about labor conditions in the chemical industry. Some works have an unusual turnover of seventy-five per cent, while others are proud of so low a replacement as two per cent a year. Between the extremes of the shifting movement of immigrant labor on the seaboard and the settled permanence of native workers in the interior, every intermediate condition can be found in the widely scattered plants of chemical industry. Unlike other types of work, chemical operations cannot be unified,

for wherever other industries require their products and wherever abundant raw materials require elaboration at the source, chemical plants must be built and operated. Thus it is that no labor problem general for this industry exists, but rather multitudes of local conditions create many local problems which are not necessarily those of other manufactures.

Conclusion. Chemical research took root earliest in the industry bearing its name, but it has extended its operations to all branches, and especially to the metallurgical and electrical industries. Growth and development have resulted from this research, not always under control or always efficient, but scientifically sound and always responsive to the degree of intelligence employed to accomplish the task. Great problems need great minds to solve them, and many of the complaints of failure in research originate from the meager knowledge of the financial and commercial leaders who have undertaken to direct them and who have controlled the funds necessary for their accomplishment.

The German preëminence in this respect has been due to its scientific leadership, enterprise, and initiative, which have received far more liberal financial support than has been the case in any other country. The German was the first to recognize the importance of the application of science to his industries, and especially the chemical industry. It has been his fixed policy always to award liberal financial support, so that through good times and bad, his research and development have continued unaffected by commercial fluctuations. Ninety per cent of the directorship of the gigantic works of that nation rests on men who have a fundamental collegiate training in college and experience in their works and laboratories. The German operator is wholly chemical in thought, word, and deed. No method of selecting leaders can improve upon the primary demand that he shall know the science behind his operations. Commercial leadership is subordinated. There is close governmental touch with conditions through the Commerzianrat and Geheimrat selected for that purpose from the high officials of these companies.

The growth of the industry in this country has to a large extent been accelerated by European developments, but we are now grown up and the future will require us to contribute our full share if we are not to fall behind.

De Tocqueville doubted the capacity of a democracy to foster

genius. "There is," he said, "a small and uncomfortable agitation, a sort of incessant attrition of man against man, which troubles and distracts the mind without imparting to it either loftiness or animation."

It remains for our democracy to learn from this criticism and to develop within our organizations a spirit and respect for applied research. The power to accomplish this involves the sacrifice of earnings. "You cannot create genius by bidding for it. It is the gift of God," and the most you can do is to provide the freedom, light, and warmth necessary for its development.

Corporations Manufacturing Chemical Products

Sulfuric Acid

Tennessee Copper Co., Ducktown, Tenn.
Grasselli Chemical Co., Cleveland, Ohio
General Chemical Co., New York (Allied C. & D. Corp.)
Pennsylvania Salt Mfg. Co., Philadelphia, Pa.
Kalbfleisch Corporation, New York
Davidson Chemical Co., Baltimore, Md.
E. I. du Pont de Nemours & Co., Wilmington, Del.

Fertilizer

Armour & Co.
Swift & Co.
Wilson & Co.
} Chicago Packers
American Agricultural Chemical Co., New York
Virginia-Carolina Chemical Co., Richmond, Va.
International Agricultural Corporation, New York
and numerous small ones

Nitrogen Fixation

American Cyanamid Co., New York
Koppers Co., Chicago, Ill.
United States Steel Corp.
Bethlehem Steel Corp.
} (Coke Ovens and By-Products)
Barrett Company, New York
Semet-Solvay Co., Syracuse, N. Y.
Lazote, Inc., Wilmington, Del.
Mathieson Alkali Works, New York
Commercial Solvents Corp., Terre Haute, Ind.
Atmospheric Nitrogen Corp., Syracuse, N. Y. (Part of Allied)

Phosphate

Mining Companies — too numerous to enumerate
Fertilizer Companies
Federal Phosphorus Co., Anniston, Ala.

Potash
- Pacific Coast Borax Company, New York
- American Potash & Chemical Corporation, New York
  (Formerly American Trona Corporation)

Alkali
- Solvay Process Co., Syracuse, N. Y.
- Michigan Alkali Co., Wyandotte, Mich.
- Mathieson Alkali Works, New York
- Columbia Chemical Co., Barberton, Ohio
- Diamond Alkali Co., Pittsburgh, Pa.

Chlorine
- Mathieson Alkali Works, New York
- Hooker Electrochemical Co., Niagara Falls, N. Y.
- Electro-Bleaching Gas Co., New York
- Dow Chemical Co., Midland, Mich.
- Berlin Mills, Berlin, N. H.

Explosives
- E. I. du Pont de Nemours & Co., Wilmington, Del.
- Atlas Powder Co., Wilmington, Del.
- Hercules Powder Co., Wilmington, Del.
- Grasselli Chemical Co., Cleveland, Ohio
- Trojan Powder Company, Allentown, Pa.
- Apache Powder Co., Benson, Ariz.

Plastics
- Celluloid Co. of America, New York
- Casein Corp. of America, New York
- Karolith Corp., Long Island City
- Bakelite Corp., New York
- American Hard Rubber Co., New York

Photographic Materials (including Films)
- Eastman Kodak Co., Rochester, N. Y.

Rayon
- Viscose Corp., Marcus Hook, Pa.
- Du Pont Rayon Co., Buffalo, N. Y
- Tubize Artificial Silk Co., New York
- American Cellulose & Chemical Mfg. Co., New York
- Industrial Rayon Co., Cleveland, Ohio
- Bemberg Corp., New York

Leather
- Du Pont Fabrikoid Co., Wilmington, Del.
- Richards & Co., Stamford, Conn.
- and many others

Lacquers
- E. I. du Pont de Nemours & Co., Wilmington, Del.

Sherwin-Williams Co., Cleveland, Ohio
Valentine & Co., New York
John Lucas & Co., Philadelphia, Pa.
Commercial Solvents Corp., Terre Haute, Ind.
Sharples Solvents Corp., Philadelphia, Pa.
Eastman Kodak Co., Rochester, New York
U. S. Industrial Chemical Co., New York

Alcohol
U. S. Industrial Alcohol Co., New York
Rossville Alcohol Co., Lawrenceburg, Ind.
Publicker Industrial Alcohol Co., Philadelphia, Pa.

Wood Chemicals
Wood Products Co., Buffalo, N. Y.
Cleveland Cliffs Iron Co., Cleveland, Ohio
and many others

Coal Tar
United States Steel Corporation
Bethlehem Steel Corporation
Koppers Co., Chicago, Ill.
Barrett Co., New York
Newport Chemical Works, Carrollville, Wis.
Semet-Solvay Co., Syracuse, N. Y.

Dyes
National Aniline & Chemical Co., New York
Dow Chemical Co., Midland, Mich.
Calco Chemical Co., Bound Brook, N. J.

Carbide
Union Carbide & Carbon Corp., New York
Air Reduction Co., New York

Medicinals
Powers-Weightman-Rosengarten Corp.
Eli Lilly & Co., Indianapolis, Ind.
United Drug Co., Boston, Mass.
Parke, Davis & Co., Detroit, Mich.
H. K. Mulford Co., Philadelphia, Pa.
and many others

CHAPTER V

THE CONSTRUCTION INDUSTRY

By W. C. Clark[1]

Definition. For the purposes of this chapter, the construction industry will be defined in a somewhat broader way than may at first blush appear natural to the layman. In its broadest sense the term is now legitimately taken to include not only the erection of new and the alteration of old buildings but also the construction of railways, roads, streets, bridges, canals, harbor works, sewers and sewage disposal works, subways, tunnels, water-supply systems, and all similar engineering projects. The building of ships, railway rolling stock, and movable machinery, which involves some similar processes, must of course be excluded, but all operations that produce a more or less *fixed* structure or alteration of the natural topography are today recognized as branches of a single great industry. Perhaps it might better be regarded as a great complex of industries because no single business organization could be sufficiently skilled in all the lines of activity enumerated to prosecute any and all of them efficiently and economically. It is true, also, that the various branches of the industry differ in many important respects and are only loosely coördinated. Nevertheless they have a common bond of unity in that to a large extent they require similar organizations, similar materials and processes, similar tools, and similar types of manual and technical skill.

So defined, the construction industry is one of the most essential, most important, most complex, and most fascinating of American industries.

Its Place in the National Life: Construction, the Index of a Nation's Progress. From the beginning of time building has shared with agriculture the distinction of being the world's most important occupation. In fact these two industries have been the

[1] Economist, W. S. Straus and Co.

only really essential industries, catering as they do to the two primary wants of man, the need for food and shelter. But since the time when the natural cave or the rude hut gave primitive man the minimum of essential protection from the elements, the importance of the construction industry's contribution to man's life has been magnified many times. It has become the *sine qua non* of modern civilization because it is responsible for the creation of the material structure which is its basis.

Obviously, then, the extent and character of its existing construction furnish an excellent gauge of a Nation's progress. The adequacy of its physical plant for production, transportation, and exchange influences materially its productive efficiency and the abundance and cheapness of the world's goods available to its people. The living standards of these people also depend very largely on the number and quality of their homes, schools, and churches, on the accessibility of varied recreational facilities, on the availability of water, gas, electricity, and sewerage facilities, and on the adequacy of roads and streets which enable them to move quickly from place to place. If these living standards are to be maintained and improved, old buildings must be repaired or replaced as they wear out, new and better structures must be erected to satisfy both old and constantly emerging new wants. For these reasons, as the Department of Commerce has pointed out, progress depends largely on the Nation's devoting a due proportion of its energies to the work of construction.

Not only does such construction contribute directly to and give an outward measure of the material well-being of the people but the architectural quality of the Nation's permanent structures attests on the one hand the mastery of its architects and engineers over the principles of æsthetic design and on the other hand provides the people with the best possible opportunity of cultivating their appreciation of beauty and grandeur. For architecture is one of the fine arts. Nowhere else do we find such a unique partnership of the beautiful and the purely utilitarian. In all works of architecture, not only must practical ends be served efficiently but the plan, masses, and adornments of the structure must be so handled as to impart to it interest, beauty, grandeur, unity, power. It is to the credit of the American architect and engineer that, in the last few years particularly, an increasing number of structures have been erected in which these two objectives have been attained

in high degree. Their towering sky-lines are increasingly the pride and boast of our leading American cities and in the mind of many foreign visitors represent the most original, and therefore most important, contribution which this country has yet made in any field of creative art. Fortunately, unlike the masterpiece of the painter's brush or the musical composition entitled to enduring fame, the products of the architect's genius and the builder's skill lie always open to the public eye, so that he who runs may possess and enjoy and learn to know beauty.

Rank as an Industry. Turning from results to economic forces, we find that the construction industry ranks as one of the nation's foremost industries. The United States Census of Occupations showed 2,467,500 employees and independent workers in the so-called " building trades " in January, 1920, a month and year of relatively low activity in building. Making allowances for craftsmen performing similar operations in other industries, we estimate that in January, 1920, 2,338,210 persons were engaged in the building industry, of whom 2,248,101 were wage-earners. This does not include 131,467 persons classified as engaged in " Street Maintenance, etc." and presumably omits many persons, particularly unskilled laborers, who would normally be employed in railroad construction and maintenance, highway building, etc. The relative importance of this number of wage-earners may be grasped by comparing it with the number of employees directly employed in other industries. Of the manufacturing industries, only the iron and steel industry with 3,107,082 employees exceeded it, while textiles, the next largest manufacturing industry, employed only 976,777 persons. In extraction of minerals, 1,018,967 wage-earners were given employment, while steam railroad transportation accounted for 1,108,424. The figures given, of course, do not include the large number of workers in the great building-material industries (lumber, cement, structural steel, brick, etc.) which depend largely on construction for their livelihood. It has been estimated that the building industry employs directly over 6 per cent of those engaged in gainful occupations and, either directly or indirectly, fills the dinner-pail of fully 10 per cent of the nation's families.

Measured in terms of volume of annual expenditure, the construction industry ranks as the Nation's second industry, surpassing transportation and exceeded only by agriculture. Unfortu-

nately accurate statistics of the exact amount of money spent on construction in the country as a whole are not available. Even for current employment of men and current consumption of materials in the industry we have statistics covering only a few states or the shipment of a few important materials from producers' plants. For most purposes we have to rely solely upon the figures representing the number and value of permits issued in a large number of leading cities as compiled by such private organizations as S. W. Straus and Co., Bradstreet's, and Dun's or upon those representing the number, square-footage and value of contracts awarded in the 37 states east of the Rocky Mountains as reported by the F. W. Dodge Corporation.

Available Buildings Statistics. Obviously these statistical series are really indexes of the building activity of the immediate future rather than measures of current operations. As they are, however, the only really comprehensive statistics available, their particular merits and limitations should be clearly understood.

Building-permit figures represent the valuations placed upon construction jobs when permits are granted (or in a few cases when plans are filed) by the building departments of our towns and cities. They therefore include small structures as well as large and alterations as well as new construction. On the other hand, they do not cover construction carried on outside of city limits, and, in some cities also, public works of certain types are not included because permits are not customarily required for such operations. The claim is made that the permit records are compiled by officials only as an incident to their administration of city building codes and that therefore the figures may represent either undervaluations or overvaluations. It is true that in the smaller cities and towns, the jobs are generally undervalued, but such tendencies are likely to persist and do not affect seriously the importance of the permit index as an indicator of changing trends in the building industry though they impair its value as a measure of construction volume.

Contract figures are collected by field agents of a competent private statistical organization and are supposed to represent the contract price of construction actually started or definitely ready to start. Where general contracts are not let, presumably estimates of cost are used. They do include large projects carried on outside the limits of cities and all public works, but they fail to

cover most low-cost new buildings, practically all alteration work and construction in rural districts. Unfortunately, they are not available for the Pacific Coast and Rocky Mountain States. In sum, contracts awarded perhaps represent for the area covered a more accurate total of construction volume already started or about to start. Permits issued, representing as they usually do an earlier stage in the construction process, are probably a slightly more sensitive barometer of changes in the trend of building activity.

Annual Volume of Construction. On the basis of this partial statistical material, estimates of the national construction volume have been made from time to time. Three such estimates for the years since 1919 are presented in the following table. Mr. Holden's estimates were based on contracts awarded and as he himself points out are to be regarded as minimum amounts because of the incomplete coverage of such figures. Those by Dr. W. I. King, formerly of the National Bureau of Economic Research, were based in part on contracts awarded and in part on building permits. Not only contracts awarded but the financial results of construction corporations published in the Statistics of Income of the Treasury Department were used by the Federal Trade Commission in arriving at its results.[1]

TABLE 1

Estimates of National Construction Volume

Year	By Thomas S. Holden	By Dr. W. I. King	By Federal Trade Commission
1919	$3,142,500,000	$4,185,000,000	$4,873,000,000
1920	3,337,600,000	4,120,000,000	5,152,000,000
1921	3,068,900,000	2,827,000,000	4,224,000,000
1922	4,329,700,000	4,021,000,000	4,877,000,000
1923	4,768,100,000	4,802,000,000	5,168,000,000
1924	5,237,100,000	5,304,000,000	
1925	6,622,600,000	6,976,000,000	
1926	6,800,000,000	7,172,000,000	

While contract records do cover engineering projects, neither of the two lower estimates presumably includes all expenditures by public bodies upon ordinary highway construction and by the railways upon new trackage and the maintenance of way and

[1] Report on National Wealth and Income, 1926, Exhibit No. 4.

structures. The Dodge figures for contracts awarded covering "Public Works and Public Utilities," in which classification is included "water-front developments, bridges and viaducts, incinerators, lighting systems, railroad construction, railway buildings, sewerage systems, highways and water-supply systems" shows an estimated total for 1926 of only $1,181,000,000. Yet the latest annual report of the Department of Agriculture estimates that the yearly highway expenditure of the United States is alone in excess of a billion dollars, and the American Railway Association reports that the total capital expenditures of the steam railroads for roadway and structures during 1926 was $513,164,000.

It seems apparent therefore that the United States must have spent upon all kinds of construction during 1926 a sum considerably in excess of seven billions of dollars. This estimate indicates that probably over 8 per cent of the total national income was expended by the building industry during that year and lends color to earlier estimates of the National Bureau of National Research showing that the percentage of construction expenditure to national income ranges from 8 to 12 per cent approximately.

This volume of construction compares with $6,449,000,000, representing the gross operating revenues of the steam railroads in 1926 and with $3,371,856,000, representing the 1925 value of motor-vehicle manufactures, the largest manufacturing industry in point of output. If only 40 per cent (a low estimate) of the total cost of construction is now represented by labor, the building industry must have paid out in wages and salaries during 1926 an amount probably in excess of 3 billions of dollars. This again contrasts with wages of $658,000,000 paid out by the motor-vehicle manufacturers during 1926 and with a railway wage bill of $2,990,000,000 for the same year. It is probable, therefore, that the construction industry is the largest single disburser of wages in our entire business community.

Relation to Other Industries and to General Business. But the industry is important not merely in its own right and for its immediate effects. Its unique position in the economic structure rests upon the far-reaching effects which it exerts upon general business conditions through its influence upon a wide range of industries and communities. Probably no other industry exerts anything like such a widely ramifying stimulus or is of more importance as a barometer of the changing phases of the business cycle.

The significance of this statement can be easily explained. An order for $5,000,000 of steel rails will give employment to a limited group of men working probably in one community in blast furnaces and steel rolling mills. Its stimulus will, of course, also be felt by those who mine and transport the ore, by the retailers of the community, and ultimately by other business groups. But contrast this stimulus with the direct and indirect results of a decision to build a $5,000,000 office building. Immediately employment is given to architects, engineers, and a considerable body of professional and technical men. When the actual construction process begins, one group after another of skilled or semi-skilled craftsmen is given employment — wreckers, excavators, foundation men, steel erectors, masons, stone-cutters, bricklayers, plasterers, plumbers, painters, and a score of others. Most of these groups will represent considerable bodies of men, drawn from several sections of the city or perhaps from several cities. Each completes its task in a few weeks or months, receives its rather generous remuneration, and carries it home to increase the purchasing power and stimulate the purchases of its community. Not only that, but the placing of the initial order has constituted a demand for lumber, cement, structural steel, brick, tile, cut stone, sand, gravel, crushed stone, lime, gypsum, glass, slate or other roofing materials, plumbers' materials, hardware, paint, elevators, and a host of other commodities. Many of these materials or products will require special fabrication for the particular job. In any case the labor of thousands of workmen scattered in all parts of the country and perhaps in many countries will be required to produce the commodities demanded. Similarly, business will be given to the railroads and other agencies which transport the materials, bulky as they usually are; and to the jobbers and dealers who deal in them. Thus, the stimulus is nation-wide; few industries and few communities fail to feel its fertilizing touch.

In the case of a number of the nation's leading industries, the demand which results from construction constitutes a very important proportion of the total demand. Thus building is normally the second largest customer of the steel industry, consuming about 14.9 per cent of the total steel output in 1927 as compared with 13.3 per cent taken by the automobile industry and 20.4 per cent by the railroads. Probably over 60 per cent of the total lumber cut in the country finds its way into construction of one form or

another. The typical building material industries, such as those producing cement, brick, building stone, sand and gravel, etc., find of course a market for practically 100 per cent of their product in the various branches of the construction industry. Finally, building materials account for fully one eighth of all freight traffic carried by the railroads.

It is obvious that variations in the volume of construction from year to year have a large share in determining the prosperity of other major industries and therefore of the country generally. Increased building activity is immediately reflected in an increasing demand for the products of many industries, in strong or rising material prices, in increased employment and in expanding purchasing power in many communities. If demand be excessive and insistent, an inflationary boom with inevitable reaction is likely to be the result. Conversely, a cessation of building activity lessens the demand for building materials, leads to depressed material prices, throws large numbers of men out of employment not only in direct construction but in the material industries as well, and reduces the purchasing power of many groups and many communities. The effect in either case is cumulative.

If the curve of building be correlated with the movements of general business, it will be found that building tends to move early in the business cycle. In the downward swings of the cycle, it tends to anticipate the turning points in general business, while in the upward swings, it may either precede or coincide with or follow them, depending upon special conditions in the construction industry itself. "In the 1904–07 cycle, for example, building permits began to rise eight months in advance of the upswing in general business; in the 1908–10 cycle, they recovered at about the same time in the spring of 1908; and in the succeeding cycle, they lagged about two months behind the general movement. On the downward movements of each of these three cycles, the building industry anticipated the decline in business by some two to six months." In the post-war cycle, the same correlation has been apparent. Thanks to the pressure of the accumulated shortage of building facilities, the building industry took the lead in the three expansion periods since the Armistice and was the first to forecast the termination of the inflationary boom which developed late in 1919.

It is little wonder, then, that a movement has developed to speed

up building when business is slack and moderate its activity in the upswing of prosperity, so that the industry may perform more efficiently its alleged function as a " balance wheel " or stabilizer of general business. Little wonder also that a theory of business cycles has been formulated which seeks the real cause of industrial depressions in the wide fluctuations of construction volume and in the corresponding fluctuations in building costs. That theory may contain only a part of the truth, but, as a recent writer has said, " It is not at all likely that this country can enjoy a real prosperity at any time when its construction industry is employed at anything much less than full capacity. It is always one of the most important contributors to general prosperity as well as one of the largest recipients of the accumulated surpluses that result from prosperity. It is not the only leg on which our economic structure stands, but it will always be one of the strongest."

Historical Development. An adequate discussion of the historical development of the construction industry in this country would require a detailed treatment of the history of American architecture, the development of the various branches of engineering, the rise of new materials used for building purposes, changing trends in the various types of building structure, and the whole story of the introduction of countless improved processes and labor-saving devices in the art of construction. While most of this development has been encompassed within the brief span of 40 years, the story is so full of incident and so complicated in pattern that only a few of the leading trends can be touched upon in the space at our disposal.

Early Building Materials and Methods. Building in early civilizations was always determined by climatic conditions and based on the materials that were close at hand. In the forested regions of the earth, wood was the first building material. The Egyptians, as Biblical history records, shaped rude huts out of sun-dried bricks of alluvial clay, with palm-tree trunks as lintels over the doorway and to carry the flat earth roof. Brick was the material of all the civilizations of the Euphrates valley. Greek architecture was a stone architecture. The Romans were the first to develop a composite architecture, using brick, stone, and concrete. In brick and concrete they were experts. They carried their knowledge throughout Europe, but after them the art of brick making and the secret of concrete were lost for centuries.

From the time of the Romans practically to the middle of the nineteenth century, when the development of industrialism created new demands and forced the development of new materials and new processes to provide structures to take care of these demands, wood, stone, and brick remained the three essential materials of construction. They, and particularly wood, were the materials used by the early Colonists in this country, who, with the architectural ideas they had brought with them based on the minor buildings of the shires of rural England, shaped them into the Colonial architecture which we admire today. The Revolution brought a desire on the part of the Fathers of the Republic to slough off provincial dependence and colonialism, and initiated the classical revival, which in the work of Thomas Jefferson and the plans for the city of Washington was based on a high inspiration but which elsewhere represented a decline from the traditional craftsmanship and art of the Colonial period. Then under a welter of new influences, chiefly Romanticism on the one hand and industrialism with its emphasis upon land-jobbing, jerry-building, and machine production of jig-saw ornamentation on the other hand, came disintegration and decadence until near the close of the nineteenth century.

Still, however, materials and processes were largely the same. Mechanical improvements, says Mumford, "had affected the milieu of architecture but not architecture itself." "Slowly, the actual methods of construction changed; the carpenter-builder, who had once performed every operation, gave way to the joiner, whose work profited by putty and paint; curtains and carpets — to the plasterer, who covered up the raw imperfect frame — and to the plumber. Weird ornamental frames for doors and window-architraves, for moldings and pendents, were supplied to the builder by the catalogs of the planing and scroll-saw mills. Invention produced novelties of contortion in wood, unique in ugliness and imbecile in design." Wood continued to be largely used for the jerry-built packing-box factories and tenements, though brick became increasingly common in the cities, and later New York fell a victim to the brownstone front.

Extensive building in the fifties of last century introduced the iron age in building construction as the previous decade had done in shipbuilding. First cast iron and after 1855 imported structural wrought iron came into use for columns and trusses and for fronts

in the then ambitious four- to five-story buildings. American wrought-iron shapes began to be made in considerable volume in 1875 and were used in rapidly increasing amounts until the introduction of Bessemer structural steel commercially in 1884. The manufacture and use of both were continued until 1894, when the production of wrought-iron structural shapes was discontinued. This iron age was a great era of bridge and railway building. Steady progress had been made by the rolling mills in establishing their standard shapes, and the work of a number of great engineers like Roebling, who is responsible both for the design of the suspension bridge and the manufacture of steel cables therefor, had produced several great and beautiful bridges, culminating in the Brooklyn Bridge completed in 1884. Railroad rails were being produced in large quantities, and the rapid spread of the railway network in the three or four decades after 1850 had given to the American construction industry an opportunity to set new speed records in grading and track-laying under large-scale organization methods.

Architectural Photo Company

FIG. 1. — The Tacoma Building, Chicago, first of the steel frame skyscrapers, erected in 1886-87.

Coming of the Steel-Frame Skyscraper. As late as the eighties the typical up-to-date business building was still eight or ten, or in rare cases twelve, stories in height and consisted of massive " masonry

bearing walls for the exterior with generally some interior masonry walls, cast-iron or wrought-iron interior columns, wrought-iron girders and joists, terra cotta floor arches serving as the floor plate and as fire protection for the steel beams and girders, terra cotta encasement of columns, and cast-iron lintels over openings in the exterior walls." The next few years were to carry forward the evolution to the stage where the masonry walls were to be eliminated as the supporting element of the structure. In this no-man's-land of development, it is difficult to demarcate definite stages of advance and difficult to assign full credit to any one individual or to any one building. At least three Chicago architectural firms must share the praise for the progress that was made. W. L. Jenney's Home Insurance Building and Burnham and Root's Western Union Building undoubtedly pioneered in certain phases of the advance, but if there is any one building which has the right to be called the first modern skyscraper, it is the Tacoma Building erected in 1886–87 from designs made by Holabird and Roche. In this building, the principle of skeleton steel-frame construction was at last definitely established. This new structural principle, which is regarded as

American Institute of Steel Construction

Fig. 2.—An architect's sketch of a suggested 75-story structure designed to represent the most economic development under the present New York zoning law.

the most important contribution to architecture since the Gothic period, means merely that the walls are supported, usually at each story, by the steel framework. The walls instead of carrying the weight of the whole structure become merely curtains enclosing the building. At the time the principle was applied to the Tacoma Building, it was regarded as a "radical, almost rash attempt," and the progress of the structure to the dizzy height of ten, later twelve, stories was watched with a grave skepticism. Its success led to immediate imitation. Five or six well-known Chicago skyscrapers were erected on the same principle in the next few years, and in New York the Tower Building at 50 Broadway was completed in 1889. But the most rapid development did not come until after the turn of the century with the erection of such structures as the Flatiron Building in 1902, the Singer Building in 1906–08, the Metropolitan Life Insurance Building in 1909, the Woolworth in 1910–13, and the new Equitable in 1915.

Distinction should be made between what made the skyscraper *necessary* and what made it *possible*. It was the rapid growth of the population of American cities, the building up of vast business enterprises requiring not only suitable buildings for factory purposes but also concentrated office space for large executive, sales, and accounting forces, the concentration of the business district in a small area, and the consequent pushing up of land values that made necessary the intensive utilization of the better urban locations. To give a fair return upon the investment in these high land values, buildings had been pushed higher and higher, but beyond a certain limit masonry could not go without thickening the supporting piers to such an extent that weight became prohibitive and the income-producing possibilities of the ground floor were ruined. Necessity therefore became the mother of invention and gave us structural steel and the elevator without which the modern skyscraper would have been impossible.

Before the elevator the maximum height of buildings was six stories, which represented the maximum stair-climbing endurance of the average tenant. The vertical screw and hydraulic plunger-type elevator which had been invented as early as the fifties gave a more or less uncertain transportation for a few stories above the walking limit, but it was not until the installation of the first successful electric elevator in 1889 that the problem of vertical transportation was really solved.

It was, however, the advent of structural steel that completely revolutionized the art of building construction as well as of architectural design. Bessemer structural steel, introduced in 1884, as already noted, was one third stronger than wrought iron. Later still, improvements in the open-hearth process made it possible to produce open-hearth steel on a commercial basis, and the latter has now almost entirely superseded Bessemer steel for structural purposes. Production of steel of a predetermined quality has

Courtesy Chanin Construction Company

Fig. 3. — Portion of truss weighing 202 tons being raised by three powerful steel derricks.

always been possible and its making in large and more scientifically designed sections has kept pace with the increasing facilities for production and the increased knowledge of structural engineering. Only recently a committee of five leaders in the academic, engineering, and architectural professions, appointed at the instance of Secretary Hoover, made recommendations for the control of designing and fabricating structural steel which were approved by the Building Code Committee of the Department of Commerce and by the American Society of Civil Engineers, and have since been incorporated in the revised building codes of nearly one hundred cities. The recommendations will reduce the amount of steel required for building purpose by using a fiber stress of 18,000 lbs.

per square inch instead of 16,000 lbs. and thus effect a considerable saving to the building public.

Structural steel is the strongest structural material in use per unit of weight and per unit of volume. It is a product made under the skilled control of factory conditions, of uniform chemical composition and physical and mechanical properties, and possesses great durability and reliability. It is because of these qualities that it has become such a paramount influence in the development of the construction industry.

Outstanding Development in Engineering. The quarter century following the introduction of the steel-frame skyscraper and the World's Columbian Exposition held at Chicago in 1893 deserves in many ways to be called the golden age of American building. A new structural system of tremendous possibilities had been initiated by the former development and the latter represented a great architectural and engineering triumph. Thereafter the whole construction industry seemed to take a new lease on life. Building volume increased seemingly in geometric progression, and every phase of the industry recorded an impressive series of advance.

Of particular importance were the developments in the various branches of engineering. Indeed, as the modern building has been aptly defined as "an establishment devoted to the manufacture of light, the circulation of air, the maintenance of a uniform temperature, and the vertical transportations of its occupants," it is not far from the truth to say that modern building has become engineering. Certainly the engineer, untrammeled by past traditions, has risen to the responsibilities of his great task. The structural engineer, whose responsibility to assure the security of a building's occupants and the owner's investment has become more onerous with the increasing size and height of buildings, has developed and used his knowledge of materials and forces so to design the foundations, columns, beams, and girders that they will give adequate support to the walls, floors, and roofs and equip the building to withstand the shocks of winds and earthquakes and resist the attack of fire. The development of "fireproof" or fire-resisting methods of construction has gone steadily forward since Edward Atkinson first developed standard mill construction for industrial buildings to reduce the fire losses which New England textile mills were suffering and since the great Chicago and Boston fires drove home the need for fireproof residential and commercial

buildings in the cities. The automatic sprinkler has made standard mill construction adequate under certain height and area limitations, while a long series of advances involving the use in succession of brick, hollow tile, and reinforced concrete for floor arches and for fireproofing steel columns and the use of hollow tile and various forms of gypsum for fire-resisting partitions have solved the problem for the large modern building. Elevator engineering has shown steady improvement, reaching towards the automatic, high-speed, multi-voltage or variable-voltage control systems of today which give the maximum of personal safety and comfort. Steam and hot-water heating have developed from crude beginnings in 1890 until it is possible to secure the utmost economy and almost ideal air conditioning by means of temperature and humidity control. Sanitary engineering has seen similar development, but most important of all perhaps has been the work of the electrical engineer. Illumination in all its multitudinous forms and effects are devised and controlled by the electrician. Everything that requires power for its performance comes within his province. The striking and innumerable advances that have been made in this most inclusive branch of engineering have "crowned the possibilities of metropolitan building development."

Reinforced Concrete. Since the invention of the skeleton steel frame, probably the most important single development in building construction has been the introduction of reinforced concrete as a building material. Made possible by the cheap production of Portland cement on an enormous scale and by the economical rolling of small steel shapes, it came into general use after 1900, following much experimentation in the eighties and the nineties. Lack of standardization of cement retarded its rapid development in the early years. Cement manufacturers therefore directed their efforts towards producing a uniform material having certain strength qualities. A big step forward came with the adoption in 1904 of a standard specification for Portland cement by the American Society for Testing Materials. The Portland Cement Association and the American Concrete Institute were organized to promote the knowledge and use of the material and both worked in conjunction with the American Society for Testing Materials. A Joint Committee composed of members of these organizations and the American Society of Civil Engineers has produced a standard specification for the designing and making of reinforced concrete.

Instruction in the design and making, placing, and testing of reinforced concrete is now included in the curricula of all engineering schools. Since 1923 special attention has been given by the American Concrete Institute and by physicists and chemists to the study of the deterioration of concrete, and the Portland Cement Manufacturers Association is engaged in an intensive effort to instruct the designers and makers of concrete in the improved methods that have been developed.

With this growth in the standardization of the product and with the spread of information in regard to its proper use, reinforced concrete has shown rapid development as a construction material. It is the standard material for improved highway construction, dams, reservoirs, tanks, sewers, and bridges within certain limitations and has become a popular form of construction for foundations, columns, girders, beams, floor and roof slabs, and walls in buildings of all kinds, ranging from one to twenty stories. It has revolutionized the design and construction of factory buildings. In its competition with structural steel, the owner's decision is determined by such factors as relative availability of the two materials, cost of transportation, type of labor supply and of supervision, adaptability to special purposes, flexibility in case of changed conditions, speed of construction, and requirements of strength and durability. As reinforced concrete is made at the job under job conditions, special vigilance is necessary to assure the selection of sound materials and honest, scientific workmanship.

Recent Advances in Construction Methods and Equipment.[1] While not so important as the introduction of new structural materials or systems, steady progress has been made by builders in the utilization of more efficient mechanical equipment and in the development of new and improved methods of accomplishing familiar results. Only a few of the more important of these devices can be mentioned.

Of outstanding importance has been the invention of the hoisting engine, now operated either by steam or by electricity, which was adapted to building purposes about 1895. In steel construction, it not only lifts heavy parts to place without the risk attendant upon raising by hand but also makes possible the use of much heavier members than would otherwise be possible, a minor truss

[1] This section draws heavily upon Chap. 7 of "Seasonal Operation in the Construction Industries," a report issued by the President's Conference on Unemployment.

weighing 125 tons having recently been placed in position by two power derricks in a New York theater operation. The hoisting engine, developed in a hundred different forms, is also applied to practically all other building materials and construction types and has eliminated "much of the labor and most of the accidents involved when laborers crawled up uncertain ladders with loaded hods or teetered up slippery planks with heavy wheelbarrows."

Courtesy of the Foundation Company

FIG. 4.—Modern foundation operations.

Excavation work has been revolutionized by a series of mechanical devices and new processes. The power shovel with a single shovelful fills a wagon which formerly took the labor of 4 men for at least 15 minutes. For most grading work, horse-drawn plows and scrapers have long ago replaced the pick and shovel and on more important work are themselves replaced by the steam shovel served by lines of trucks and by drag lines and cableways which deposit excavated material well away from the excavation. Trenching is now usually done with special power-driven machinery which cuts to line and grade in one operation. Back filling has its own special equipment. The caterpillar tread applied to all these forms of mobile equipment has made them more effective in soft or wet ground and easy to move from place to place. When

heavy mechanical equipment is not economical, pneumatic or electrically driven picks may be used to multiply efficiency in frozen ground. For rock excavation, hand labor has succumbed almost entirely to steam-driven machinery or the pneumatic drill which can strike one hundred blows to the laborer's one. Pile driving by steam-driven hammers supplied from a stationary boiler or from any steam-driven equipment has displaced the archaic custom of raising a heavy weight between crude guides by means of horse-drawn cables. Incidentally steel and concrete pilings are being increasingly used.

The application of compressed air to rock drilling has already been noted. Since 1900, through the pneumatic hammer, which has been steadily improved, it has been used to meet the need for the economizing of time and labor in riveting the joints in steel structures, but its use for this purpose is now being threatened by the demand for the noiseless electric welding process.

The invention of the familiar concrete mixer alone has made possible the use of concrete on its present tremendous scale. Not only have time and labor been saved but the efficiency of the process has been greatly improved and the season during which concrete may be used has been lengthened by the automatic mixer and by various portable heating arrangements.

In highway construction the recent trend is towards lower grades, reduction of curves, and permanent hard-surfaced pavements. Most of the advances in excavating and in concrete production are of course applicable in this field. Increasing use of power-driven and other improved mechanical equipment and centralization of processes are represented by power ditchers, industrial railroads and central mixing plants for concrete or bituminous aggregates, the scarifier for tearing up hard pan and old road beds, various surface-finishing devices, and numerous other improvements.

Many of these mechanical appliances and improved methods are applicable to railroad construction, which in these days is largely confined to the reduction of track grades, the correction of short curves, the reduction of mileage by cut-offs, and double tracking. All these changes are for the purpose of reducing the mechanical haulage effort to a minimum, and increasing the speed and safety of transportation. For the same purpose, rails are being made much heavier, bridges are being strengthened or replaced by more

modern structures, automatic signals and interlocking switches are being installed and freight and passenger terminals are being enlarged.

Finally one should never overlook the really important contribution made to all branches of the construction industry by the development of the motor truck, which has provided more rapid and dependable movement of materials under normal and extreme conditions and has permitted the economical use of larger units of mechanical equipment.

The New American Architecture. Without attempting to trace the history and contributions of the Rómanesque experiment, the Neo-Classical revival, the French School, the Italian School, and the various other " movements " in the architectural history of the last forty or fifty years, we may note a gradual improvement in design and planning since the eighties, an improvement which doubtless rests upon the individual genius of a few dominating personalities, upon the spread of architectural education since the founding, in the late seventies, of the first school of architecture, and upon the increase in traveling and reading by the average layman who in increasing numbers is now demanding an interesting and beautiful architecture and who has the means to pay for what he wants. In particular, progress has been made with the design of the small house, where the substitution of sun-rooms, sleeping porches, kitchen closets, etc. for parlors, pantries, and attics have made a more convenient and more livable dwelling; the prosperous country home where a tradition of good building and dignified design has been established; the low-height public buildings like libraries, art galleries, college buildings, churches, and municipal institutions, where for the most part old-world models do not clash with new materials and purposes; and in the field of landscape architecture.

Less progress has been made, at least until recently, in the design of tall building. It is true, of course, that tremendous strides have been made in the planning of interior arrangements and the floor layouts of the modern office, apartment house, and apartment hotel buildings, particularly from the point of view of reducing waste space and adding to comfort and convenience. But there are critics who, while recognizing the skyscraper as an American structural contribution of the first importance, nevertheless declare that the solution of skyscraper *design* has been

"unbelievably bungled for twenty-five years." The truth in this criticism lies in the fact that the American architect, suffering from the inhibitions of tradition, has too frequently failed to make the necessary architectonic coördination between exterior design, new materials, and interior plan and equipment. In other words, he has attempted to adapt classical styles invented for one-story buildings to multi-story buildings. He has brought Old World traditions to the treatment of the American skyscraper,

Fairchild Aerial Surveys, Incorporated

Fig. 5. — Downtown New York City.

forgetting that the ornamentations of the horizontal architectures of Europe had definite structural purposes as braces or supports or were appropriate only for comparatively low buildings.

Granted the validity of this criticism, it must be admitted that we are now on the way to a true solution of the skyscraper problem. In such buildings as the Shelton Hotel and the new Telephone Building in New York City, architects possessing vision, courage, and the creative instinct have made entirely successful attempts to solve the problem of designing tall buildings used for industry and commerce. The stimulus of these history-making attempts is rapidly spreading and, influenced by the zoning regulations of our leading cities, there is being developed an architecture more

beautiful and better adapted to its uses than any heretofore existing. As all architectures spring from the needs and customs of a people, the new American architecture will be the representation in steel and stone of the civilization and culture of the industrial and commercial age.

Business Organization of the Industry: Non-Repetitive Operations. Certain conditions in the construction industry cannot be understood until some of the special characteristics of the form of business organization which it has developed are explained. These special characteristics are a product of conditions under which modern large-scale building operations must be carried on.

Unlike ordinary manufacturing, building operations are not continuous or repetitive. Each building project represents a special job which requires architectural planning and structural activity peculiar to itself. It might be compared to " custom work " or to a " special order " (with special specifications) going through a factory, except that not even the factory remains the same for two successive orders. The new work must be carried on each time in a new place and under different governing conditions. Obviously this changing locale and these constantly changing specifications make it impossible to introduce, at least to any considerable extent, those principles of standardization and mass production which America has applied with such astounding success in the so-called factory industries. On the other hand, the industry's complete dependence on an individual local demand frees it from most of the problems of national and international competition. Many building materials are subject to such competition, but except in a very indirect way completed buildings compete with each other only in a limited local market.

The Contracting System. Because of these and other basic conditions, a type of organization has developed in the industry which has few parallels in the manufacturing field. True, the " contracting system " still persists in certain branches of the clothing industry in certain markets, but nowhere is this system so highly developed and nowhere does it dominate the field to such an extent as in the business of construction. Striking evidence of this is found in the universal use of the word " contractor " as synonymous with builder. The builder as he exists today is a creature of the last four centuries and particularly of the period since the industrial revolution with its increasing complexity of industrial

enterprise which demands both specialization and coördination of specialized efforts. The builder of antiquity was a builder in the literal sense, he was indeed both builder and architect. The builder of today is essentially a chief executive who organizes and details the work of many specialized trades to carry out the plans of the architect. In the United States, he is usually a contractor who, commanding certain financial resources, assumes a concentrated responsibility and subdivides it among many subcontractors, each supposed to be technically qualified to perform a certain part of the work. Usually he has, it is true, special experience in and assumes immediate responsibility for, one or two of the major branches of the operation, such as the masonry or the steel work, but his chief qualification is an aptitude for executive organization, an ability to " get things done " efficiently and on scheduled time.

Forms of Contract. In all such cases, a single contract describing the work to be done, terms and methods of payment, and the responsibilities of all parties is drawn up by the architect acting as agent for the owner and is signed by the general contractor. According to the method of remunerating the contractor, such contracts may be classified as lump-sum, cost-plus or unit-price contracts. In the lump-sum contract the contractor agrees to perform all the work required by the plans and specification for a lump sum or definite stipulated amount. If, when the building has been completed, the amount paid by the owner exceeds the contractor's payments for labor, materials, and other items of cost, the difference represents the latter's profit. This form of contract is probably still the most common. Its merit is the very great one that the owner is assured beforehand what his cost is going to be. This assurance, however, is sometimes more apparent than real because of the difficulties and uncertainties, raised by adding extra work which is not in the contract, which are almost bound to arise in all projects of any magnitude. Moreover, this form of contract puts the contractor in a frankly commercial position, and unless the latter be highly responsible the pressure of an interest at variance from that of the owner may lead to skimping of quality.

In the cost-plus contract, the contractor is reimbursed for the actual cost of the work to him, and in addition for his own services is paid either a fixed fee or a certain percentage of the cost. Frequently the contractor also guarantees that the sum of the actual cost and his fee will not exceed a specified maximum sum. The

"savings," that is, the excess of the guaranteed maximum price over the sum of the actual cost to the contractor and the contractor's fee, may revert entirely to the owner or be divided between owner and contractor in a stipulated ratio. Provided the contractor is honest and competent and provided also that proper checking of labor, materials, services, etc. is done at the job by the architect's or the owner's representative, this is probably the most equitable and satisfactory form of contract. It tends to establish a quasi-professional instead of a purely commercial relationship between contractor and owner, thus tending to assure a better quality of work; it permits plans to be developed as the work progresses and thus allows greater freedom in making changes; and it has obvious advantages where, as in the case of alterations, the ultimate cost cannot be foreseen with reasonable accuracy.

In unit-price contracts, individual unit prices are named as the amount the owner agrees to pay to the contractor for each unit of work of that class performed by him. The architect agrees with the contractor as to the number of units of work actually completed as the work progresses. This type of contract represents merely a form of the piece-work system.

A more important classification of contracts is based upon the amount of work covered in the contract. Thus, the single-contract system is that in which a general contractor accepts responsibility for practically all phases of construction involved in a particular operation. This system has been subject to some criticism and compared unfavorably with that in vogue in England, where the builder is usually a contractor of considerable experience who has an intimate knowledge of all building trades and who employs directly foremen and artisans in each of them. Unquestionably the sub-contracting system has its disadvantages and gives rise to many abuses, especially where it is combined with another feature of the construction industry, the system of competitive bidding. These disadvantages will be discussed in detail in a later section.

Suffice it to say here that despite its defects the sub-contracting system is a natural and probably an inevitable outcome of the complex conditions under which modern large-scale building must be carried on. The large and constantly increasing number of specialized trades now required for the building of a modern skyscraper and the technical knowledge necessary to control some of them is so great that it would be next to impossible to unite their

operations efficiently and economically under a single administrative direction. Further, the huge size of a modern skyscraper and the rapidity with which the enterprise must be completed, once the initial commitments have been made, make two or three such contracts a sufficient responsibility for any but the largest organizations. Now, as already explained, each individual operation requires a succession of trades (wreckers, excavators, foundation men, steel erectors, bricklayers, etc.) rather than a coöperation of them at any one time. Obviously a builder would have to have a large number of contracts, arranged ideally in proper sequence, in order to utilize economically a permanent force representing all the trades. Much greater efficiency and flexibility is secured when it is possible for him to sub-let each branch of the work to a subcontractor, who will bring a " gang " of craftsmen of the right type precisely when needed, and as their work is completed transfer them to perform other sub-contracts on structures less advanced. In other words, the sub-contract system has developed because it permits the most effective distribution of many kinds of technical skill upon a very large scale. Its abuses may be corrected by minor modifications and developments, but the system is not likely to be uprooted altogether.

Incidentally it may be noted at this point that the old method of " day's work " still prevails to a small extent, especially in the case of work let by public authorities or in private enterprises where the work involved is difficult to determine in advance. The system does tend to encourage good workmanship because compensation is proportionate to time spent, but this merit is counterbalanced by the corresponding defect that the responsibility for cost is removed from those who alone can control it. Its steady decline is probably due to the verdict of greater costliness passed upon it by the court of last resort.

Competitive Bidding. Under this system the architect draws the plans and specifications embodying the owner's ideas and then delivers them to a number of contractors with an invitation to submit bids stating the amount for which they will agree to erect a building in accordance therewith and the date on which construction will be completed. The contractors in turn examine the plans and specifications for the purpose of ascertaining the quantities and nature of the units of work to be done. The quantities are tabulated and values are then placed on the units of work. The

values of materials to be purchased and of sub-contract work are determined by taking bids from material supply dealers and from the sub-contractors to whom various parts of the work are to be sub-let. After preparing a tentative time schedule showing the time allowed for the various operations and the date on which the building should be completed, the contractor submits his bid to the architect. The architect and the owner then go over the various bids received from the contractors and select the contractor to whom the contract is to be given.

On the assumption that the relative desirability of the bids would be in inverse order to their respective amounts, it would seem a simple process to make the selection by choosing the lowest bidder. This might be true if all the bidders were firms of equal responsibility and competence. Rarely, however, is this the case. The best builder of a given locality may be pitted against the worst, and the latter under the system of competitive bidding is subject to severe temptations. Obviously each bidder, in order to get the job, will use every endeavor to keep the price down. As this cost will depend primarily upon the bids he gets from his sub-contractors, the temptation is strong to invite a host of sub-contractors to bid to him and not to inquire too closely as to the honesty or competence of the lowest bidders who accept his invitation. Therefore, unless the greatest care is taken to include in the original invitation only general contractors of the highest character, the lowest bid is likely to come from a contractor who has based his bid on the lowest sub-bids, which in turn are probably those of the least responsible sub-contractors. If such a contractor gets the contract, he will probably use all "the tricks of the trade" still further to depress the sub-bids. The inevitable effect upon the integrity of the work of the single-contract and competitive-bidding system thus operating at its worst does not need to be described in detail. Such conditions are not usual and are deplored by none more sincerely than by the honest and capable elements of the building profession.

If these abuses of the system are to be avoided, or at least largely avoided, the owner and architect must see that the invitation to submit bids is given only to the most reputable, competent, and responsible contractors. Under such conditions, the system of competitive bidding should result in the selection of an honest builder, skilled in building construction, furnished with ample

capital and equipment and with demonstrated ability as an organizer and administrator. Granted such a selection, the single-contract system will probably be found the most satisfactory type from the owner's point of view because it centers upon a single contractor full responsibility for the entire complex operation. No matter how little of the work he performs with his own staff, he acts as a clearing house through which all orders and communications are cleared, he accepts responsibility for every act or failure of the score or more of sub-contractors, he marshalls materials and men in the right proportions at the right times and places and coördinates all the varied forces and operations to the supreme end of completing the structure in accordance with the plans and specifications upon scheduled time.

Another method of escaping some of the chief evils of competitive bidding and a single contract involves a partial return to the old system of separate contracts. In particular, the more difficult and critical branches of construction, such as the plumbing, heating, ventilating, electrical work, and elevator installation, are let out on separate contracts direct to contractors whose own staff actually executes the work involved. This separate contract system has the recommendation of the American Institute of Architects, is required in certain states for public works and is increasingly common in private enterprise. In some cities, Chicago for instance, it receives special encouragement from the attitude of certain trades whose members refuse to participate as sub-contractors under any general contract. It enables the owner and architect to give special attention to the letting of each contract and to confine the invitations to sub-contractors of known competence and probity. The claim is also made that such sub-contractors will frequently figure more closely in such direct bids to the owner than they would in bids sent to a general contractor. If the owner has confidence in the general contractor, the successful bidders on separate contracts for branches of the work not in the general contract may, with their consent, be placed as "subs" under the general contractor, who will of course be paid a commission for managing them.

In a still more radical attempt to avoid current abuses, separate contracts are sometimes let on all branches of the construction operation. In essence, therefore, this system involves merely the substitution for a single contract with a general contractor of a score

or more of separate contracts with the master mechanics of the several trades, and for the executive direction of a general contractor that of the architect. The method is likely to assure a reliable and capable contractor for each part of the work, but its success in practice obviously requires on the part of the architect executive capacity of a high order and a well-equipped office. Its field will probably continue to remain a restricted one.

Managerial Efficiency in the Industry The charge is frequently made that from the standpoint of managerial efficiency, the building industry as a whole has lagged materially behind some of our other leading industries. Without reflecting in any way upon the efficiency of the leaders in the industry whose organizations represent excellent examples of American business enterprise, it must be admitted that there is much truth in the criticism that conditions in the industry are as a whole still chaotic and comparatively backward.

The reasons for this comparative backwardness are not far to seek. In the first place the relatively small amount of capital required for all but the largest operations, the absence of heavy investment in fixed capital, the system of letting contracts and subcontracts, and the general character of the organization of the industry have made it possible for many thousands of individuals to set themselves up as contractors. Many of these contractors are necessarily lacking in knowledge, experience, financial and even moral responsibility. The large number of contracting firms of this type and the ignorant and irresponsible competition which has resulted have not only tended to disorganize the industry and drag down the general standard of efficiency, but also made it exceedingly difficult to raise that standard by coöperative effort.

In the second place, so many different interests are involved that unity, coöperative effort, close-knit organization for the industry as a whole are difficult to achieve. Owner, architect, consulting engineers, general contractor, a score or more of subcontractors, dozens of different types of laborers skilled and unskilled, a host of material supply men, the financial house supplying the bulk of the funds, the building department of the city granting the permit to erect the structure — each of these has his separate function to perform, his separate interest to protect in each individual operation. The coördination of all these diverse interests can never be ideally smooth and effective. The industry is almost

bound to appear disjointed, disorganized, chaotic. This is in part merely a tribute to the difficulty of its problems, the complexity of the conditions under which it operates.

Finally, the problem of detailed management in any specific building operation of magnitude is particularly difficult. It requires not merely the advance preparation of estimates on which the job is to be taken and on which the contractor is to stand or fall, the actual taking of sub-contracts, the purchase of varied materials sometimes in fluctuating and relatively unorganized markets, and the employment of foremen to handle the work, but also the most careful advance analysis of all details of the work, the arranging of the work of the various trades, the scheduling of operations and of the delivery of materials so as to coördinate the various divisions of work with the necessary materials, the planning of the work of individuals and groups of workmen, the design and maintenance of the proper equipment, the keeping of adequate cost records, the knowledge of what constitutes a day's work, the development and execution of proper policies of employment, and the efficient administration of a large and changing labor force so as to insure continuous and maximum performance. Rarely does the task of management call for such a combination of qualities and for the exercise of its functions under such pressure as to speed.

When this inherent difficulty is combined with the constantly changing character and situs of activities and with the ease of entering the industry, it is not surprising that the average efficiency of management is below that of the leaders among American manufacturing industries.

Recent Improvements. In the last few years, however, very distinct progress has been made in raising this low-average efficiency nearer to the level set by the leaders in the industry. In particular progress has been made in applying to construction operations the principles and methods of scientific management developed in the modern factory. It will be recalled that the Committee of the Federated American Engineering Societies, which studied the problem of industrial waste in 1921, found amongst contractors frequent evidence of "haphazard management in planning and controlling work and lack of standards, which often double the labor cost." Failure to furnish continuity of employment; failure to plan work in sufficient detail; lack of proper schedules to allow

efficient coördination of scheduling, purchasing, and delivery with job requirements; lack of standards and adequate cost methods as a means of checking production; failure to use proper amount or type of equipment; waste of material through careless handling and improper plant operations; high labor turnover; and inadequate employment management were the chief manifestations of inefficient management which received the criticism of this Committee.

The leading firms in the construction field had, of course, long recognized the wastes in money and labor-power which these defects in management involved and had adopted methods that approached modern factory management. But the intense activity in building during the last four or five years and the tremendous pressure upon the industry gave a new stimulus to the study of managerial problems, to the introduction of improved practices even by the better firms, and particularly to the spread of this improved technique to the firms which had formerly lagged behind the leaders in the industry. One evidence of this new interest in management is the establishment in a number of leading universities of courses in construction for the scientific training of young men who desire to rise to positions of responsibility in the building industry.

In addition to the more general practice of advance planning and job scheduling the wider use of properly determined standards and the spread of uniform cost-accounting methods, considerable progress has been made in the invention or improvement of mechanical equipment and its wider use by contractors generally. In regard to the lack of proper equipment, the Committee on Waste in Industry had reported as follows:

"Contractors, by failure to make thorough studies to determine the amount, type, and best location of plant and equipment, add another contribution to waste. . . .

"The possibilities of savings by the application of more plant engineering are enormous, since the cost of all operations is affected by the equipment used in handling materials, the location of this equipment, and the efficiency with which it is utilized. General failure of the industry as a whole to develop, and use a greater amount of mechanical equipment is an established fact. Greater strides have been made in almost every other industry in the application of mechanical means as labor-saving devices and production

stimulants. Contractors should realize this and develop this side of the industry."

Scarcely a week passes without some evidence that the building industry has given heed to these strictures and suggestions. Nearly every issue of the technical papers in the building field contains a description either of some new labor-saving device or of an improvement of an old piece of equipment or process or of a particularly efficient piece of plant engineering on some current project.

Coöperative Self-Help. Of equal importance is the progress which has come as a result of coöperative effort on the part of the various elements of the industry. No longer is the industry as disorganized and chaotic as it was even at the close of the War. Local and national associations, now numbering over 250, have been formed to investigate the common problems of their members, supply statistical and other information, coöperate with the professions and government departments interested in construction, and in these and other ways provide leadership for their industry. The Associated General Contractors is now at work on a score of major problems confronting contractors and has laid out a program of action and coöperation which should make for rapid strides in the elimination of waste and in the raising of standards within the industry. Publication of an official journal (" The Constructor "), provision of opportunity for joint discussion through national and local conventions, research activities in connection with construction problems, establishment of close coöperation with government departments, architects, engineers, bonding and equipment companies, etc., legislative activities and persistent effort to raise managerial standards by the encouragement of simplified standard forms, cost accounting, quantity surveys, etc., constitute the chief lines of action followed by the Association in its attempt to better general conditions.

One of the chief obstacles to joint study and progress in the past has been the antagonism frequently existing between the contractor and the engineer or architect, and their failure to coöperate intelligently for the benefit of their mutual clients. This coöperation is now being provided for by Building Congresses in a number of important cities and by such organizations as the American Construction Council, which attempts to bring together all the component elements of the building industry in " a conference

association representative of the whole construction industry," and imbued with the desire to place the industry on a high plane of integrity and efficiency and to correlate the efforts towards betterment made by all existing organizations. The encouragement of better craftsmanship; the supply and training of apprentices; the standardization of practice, design, materials, and equipment; the improvement of contract forms and specifications; the simplification of building codes; and the provision of facilities for the arbitration of disputes are among the more important problems which have been subject to careful investigation by these coöperative groups.

Governmental Coöperation. Much of the inspiration for these progressive movements in the construction industry has come from the Federal Government which, though without legal authority to compel action, has nevertheless used the weapons of research, educational propaganda, advisory committees, and voluntary conferences to stimulate and guide progressive advances in the industry.

After Mr. Herbert Hoover, practical engineer and constructive statesman, became Secretary of Commerce, one of his first acts was the organization of the Division of Building and Housing in his Department to coöperate with the various branches of the construction industry in solving a number of outstanding problems which the depression of 1920–21 had brought into the limelight. In several important fields a substantial contribution has been made by the experts of the Division.

One of the greatest barriers to improved and more economical building standards has lain in the more than 600 city building and plumbing codes, designed to assure structural safety and reduce risks to life and property but showing little uniformity as between various cities and frequently wasteful as to material without, however, assuring the degree of safety intended. As individual cities had not the facilities to undertake the extensive research necessary to put the code requirements upon a complete scientific basis Secretary Hoover appointed an Advisory Committee on Building Codes, composed of engineers and architects of national reputation, to draw up model building code provisions. Six reports have already been completed which have been accepted by bodies formulating codes in 80 cities and by enactments adopted in 7 states. In many cases tests were undertaken at the Bureau of

Standards or special investigations made of the actual performance of various materials under different conditions in actual construction. Somewhat similar work has been done by the Division in the encouragement of zoning and city planning by the preparation and dissemination through an advisory committee of " A Zoning Primer " and " A Standard State Zone Enabling Act." Since this work was undertaken in 1921, the number of zoned municipalities has increased from 40 to 500, the latter including over half the urban population of the United States. Through still another Committee, the Division has undertaken to reduce the delay, annoyance, and expense involved as a result of the lack of uniformity in the mechanics' lien laws of the various states and has prepared a tentative draft of a Mechanics Lien Law Act which can be used as a basis for uniform state legislation. Much also has been done to encourage home ownership through coöperation with the Architects' Small House Service Bureau and the dissemination of information in regard to the building and financing of soundly constructed dwellings.

Perhaps of most importance, however, has been the work of the Division in collecting and distributing basic statistics relating to building activity and the production, consumption, and current stocks of building materials for the guidance of business groups and others concerned with stability. Its activities in connection with the movement to eliminate seasonal fluctuations in the construction industry will be considered in a later section.

Excellent work has also been done by the Division of Simplified Practice of the Department of Commerce in arranging for the simplification of materials and sizes by joint conferences with the manufacturers of the various building materials.

Labor and the Building Industry: Post-War Shortage of Skilled Craftsmen. Apart from the magnitude of construction expenditures, the most notorious fact about the building industry in the early post-war years was the shortage of skilled building craftsmen, a shortage which in some trades has only recently ceased to be acute. This shortage was not wholly explained by the sudden, abnormal expansion of demand. To the amazement of those not closely connected with the industry, the 1920 Census had shown that the supply of skilled building craftsmen had not only failed to keep up with the general increase in population, but had actually, for the group as a whole and for some of the more important

crafts, declined substantially from the 1910 figures. In only four trades had the number of journeymen increased; in one of these cases (carpenters), the increase had far from kept pace with population increase, while the other three cases (electricians, plumbers, and structural iron workers) represented instances where changing economic conditions and types of construction have made necessary an abnormally large increase in workers. Especially significant were a 22.5 per cent decline in brick and stone masons, a 19.8 per cent decline in plasterers (exclusive of cement finishers), 26.7 per cent decline in paperhangers, a 9.1 per cent decline in painters, a 28.3 per cent decline in building laborers, a 6.9 per cent decline in the total number of wage earners engaged in the industry, and a general decline practically all along the line in the number of apprentices entering the various skilled crafts. Some qualification should perhaps be made for the different months in which the two Censuses were taken and for the differing activity of the industry in the two years, but such a qualification would be only a slight one.

The seriousness of the problem involved in the shortage of skilled craftsmen and a declining number of apprentices was aggravated by the fact that the number of journeymen in all crafts contained an abnormally large proportion of workers over 45 years of age.

Full realization of these facts did not come until early in 1923, when expanding building demand led the contractors to bid furiously against each other for the scanty labor supply, and this in turn caused the "snowballing" of wages and the bonuses about which so much has been heard in recent years. When the industry and the public were finally awakened to the gravity of the situation, steps were taken to analyze the causes of the shortage and to develop remedies for it. The factors responsible for the shortage and the extent to which they have been already counteracted, or will be counteracted in future years, by deliberate coöperative action or by changing economic conditions may be summarized as follows:

1. The limitation of immigration, first by the War and later by legislation, has undoubtedly been an important influence reducing the supply of skilled and unskilled workers. Before the War, skilled building craftsmen, especially in the Eastern states, had been to a large though decreasing extent recruited from abroad, particularly from northwestern Europe. The war cut off this supply altogether and the post-war immigration limitation acts,

coupled with the strict laws against contract labor, the high initiation fees charged by many of the building trade unions, the exclusion of foreigners from membership in certain crafts, and the conditions of employment in some European countries, have kept the inflow from attaining its former dimensions.

2. Perhaps the most important cause of the shortage of skilled craftsmen has been the failure of the apprenticeship system to perform its important function. While the regulations of the trade unions restricting the number of apprentices per journeyman or per shop and imposing high initiation and transfer fees had usually received most of the blame, investigations by the New York Building Congress and by other impartial authorities seemed to indicate that this failure was also due in considerable part to the employer. The contract system, the lack of effective control by the employer over the apprentice, the increasing pressure for speed in construction, and the other conditions under which building is carried on today had made it easy for the contractor to overlook the necessity for training skilled labor until the demand for building had reached an unwonted peak and he had found it next to impossible to get an adequate supply of labor to fulfill his contracts. The apprentice had been too apt to be considered as a nuisance on the job; hence little enthusiasm had been shown in taking him on or in encouraging him to move ahead where wages would be higher. In most cases, therefore, it was found that the employer was not utilizing anything like even the number of apprentices allowed to him under the trade-union rules.

The industry soon realized that the old apprenticeship system had broken down under the force of modern economic conditions. Gradually, therefore, and with groping efforts, the endeavor was made to substitute a system of training more in keeping with the demands of today. In the last four or five years, much progress has been made as a result of the coöperative efforts of the Federal Board of Vocational Education, the Boards of Education of various cities, the architects, the trade unions, the contractors and such bodies as the New York Building Congress, the National Congress of the Building and Construction Industry, and the American Construction Council. Methods vary as between closed-shop and open-shop communities and as between the various trades, but into these details we cannot enter. Suffice it to say that in 75 or more cities throughout the country, apprenticeship

schools of one type or another are sponsoring a combination of theoretical and practical training which has done not a little to replenish the depleted ranks of skilled building labor.

3. Whether the apprenticeship schools will continue to recruit and train sufficient youths to compensate for the heavy drain, by death and retirement, upon the ranks of skilled building craftsmen and to take care of the gradual growth of population and the building industry, it is of course impossible to say. To many observers, however, it seems somewhat doubtful. In all periods of building boom, some labor shortage has always appeared, at least in certain crafts or in certain localities, and future developments are apt to aggravate rather than alleviate this condition. The simple fact is that the building industry has not appealed, in the past generation at least, to the native American worker. The limited extent to which the artisans already in the industry have apprenticed their own sons in the building industry is highly significant. It is unfortunately true that the industry has certain disadvantages which handicap it in its competition with other industries for the brains and brawn of young America.

(*a*) In the first place, building is a highly seasonal industry, giving no assurance of regular employment throughout the year. Indeed, few workers have an opportunity to work more than nine months out of each twelve. If, therefore, earnings in nine months are not sufficient for twelve months' living or not equal to twelve months' remuneration in competitive industries, the craft tends to be depleted.

(*b*) The industry does not furnish the " white collar " job which the American workman seems to demand. Instead, under current conditions it seems to require that the building artisan not only carry on his work but also go to and from his work, with dirty overalls and begrimed hands and face.

(*c*) It is largely an outdoor industry, frequently making necessary the execution of the laborer's tasks under conditions of physical discomfort or even hardship.

(*d*) It involves, particularly in certain crafts, a high degree of risk of loss of life or limb.

(*e*) The necessity of indenturing oneself as an apprentice for three to five years is not relished by the modern boy. To him, it smacks somewhat of economic slavery and restricts too narrowly the possibility of increased earnings. Hence it tends to lose out in

competition with machine industry and even with blind-alley trades. Many boys prefer to go to a factory and learn to operate a machine so that in a few weeks they may earn as much as men who have been working at that class of work for many years rather than apprentice themselves to a bricklayer or to a plasterer and wait at least four years before they can earn full wages.

(*f*) The industry offers few channels of promotion to positions of executive responsibility, an opportunity which the ambitious American youth demands.

Labor Organization. The skilled trades in the construction industry have always been one of the strongholds of trade-union organization. A recent elaborate investigation by Dr. Leo Wolman [1] indicated that in 1923 the building trades ranked fourth among the major divisions of industry in the percentage of workers organized, this percentage having increased from 16.4 per cent in 1910 to 25.5 per cent in 1920. Since 1897, nearly half of the total membership of American unions has been in the building and transportation groups, building alone accounting for from 15 to 22.3 per cent. The dominant organizations among the building trades today are the old and well-established unions which were operating with considerable power even before 1897. The growth in membership of these unions since that date has been fairly steady, interrupted only temporarily by the more important business depressions and less affected than most industries by the decline after 1920. Among the more skilled craft workers, the percentage of workers organized is, of course, very much higher than the average for the industry as a whole. For instance, in 1920 the percentage of organization was 50 per cent for brick and stone masons, 40.5 per cent for carpenters and joiners, 29.1 per cent for painters, 46.6 per cent for plasterers and 33.5 per cent for plumbers and gas fitters. Considerable variations also exist as between different cities and localities. The larger cities, of course, show the greatest union strength. Brick and stone masons, for instance, were reported 95.8 per cent organized in Boston, 79.7 per cent organized in Chicago, 79.4 per cent organized in Cleveland, and 59.3 per cent organized in New York, the lower percentage in the last-named case being doubtless due to the lack of union control over the many small building operations in the outlying areas of the city.

[1] The Growth of American Trade Unions, 1880–1923. Published by the National Bureau of Economic Research, 1925.

Explanation for the comparatively high degree of organization in the building trades is to be found in such factors as the following: the age of the building crafts and the fact that their unions were among the earliest labor organizations to be established, the high degree of skill required by certain crafts and the possibility of limiting through the apprenticeship system the number of those who should be allowed to acquire such skill, the almost complete absence of women from building occupations, the limitation of the mechanization process largely to less skilled trades (as, for instance, the hod carriers), the fact that the recruiting of labor for most jobs was in the hands of the business agents of the unions, and the further facts that the industry has not been recruited largely by immigrants and that until quite recently it was almost wholly unaffected by the newer type of immigrant from southern and eastern Europe and by importation of negro labor from the South. Perhaps also the movement towards organization has been accelerated by the evils of the contracting system and the highly seasonal character of employment, which emphasized the need for collective bargaining, and by the obvious possibilities of great power resulting from strong organization of the key trades, which sharpened the taste for such power.

There can be no doubt that the dominant unions have exercised enormous power and not always with the utmost wisdom. Economists agree that a *prima facie* case for the closed shop can be made out only, if at all, where the open union prevails. At certain times in certain cities conditions have existed in the building trades which approached the closed shop with a tightly closed union. Perhaps more than any other labor organizations, the building crafts have been criticized for alleged arbitrary limitation of union membership to a favored few and for numerous work-making and output-limiting rules. Doubtless in many cases the provocation was great, the ethics of other elements of the industry not without reproach, the need for protection against exploitation of the worker important, and, as already indicated in another connection, the criticism not always wholly justified. It is also probably true that only in relatively rare cases do the graver abuses exist today.

Bitter struggles have frequently marred the relations of labor and capital in the industry, particularly in those cities in which the employers have attempted to retain or restore the open shop. In

one of our leading cities, a so-called Citizens Committee in a public advertisement recently listed as existing unfair practices in the industry "illegal conspiracies between union labor, contractors, and manufacturers of material; limitation of output; repudiation of contracts; boycotting; sympathetic and jurisdictional disputes; intimidation; sabotage; graft; bombing; slugging and killing." In another leading city, "a czar for the building trades" is being suggested as a method of correcting a somewhat similar, though much less serious, situation. Obviously, if such practices exist, an important labor problem remains to be solved.

In the past a very large proportion of the strikes occurring in the building industry have been controversies between two or more unions as to which should perform certain work on a structure. Such unfortunate family disputes are arising continually because of the constant introduction of new materials for certain processes. To alleviate the situation there has been formed a National Board for Jurisdictional Awards consisting of representatives from the Building Trades Department of the American Federation of Labor, the American Institute of Architects, the Federated American Engineering Societies, the Associated General Contractors of America, and the Building Trades Employers Association to which such disputes are now referred. This Board has met with considerable success in settling such jurisdictional disputes and thus eliminating much delay and expense for which the employer was in no sense to blame.[1]

Eliminating Seasonal Fluctuations in Construction. Reference has already been made to the fact that the construction industry is subject to wide fluctuations of activity from month to month and from year to year. Such fluctuations obviously create serious labor and managerial problems, increase construction costs, and to the extent that they can be avoided represent sheer economic waste. The last few years have brought a keen realization of these facts on the part of the public and have witnessed the initiation of a campaign to "regularize" the industry or at least to study how greater "stabilization" of building activity may be secured.

[1] At its annual convention held in Los Angeles in October, 1927, the American Federation of Labor decided to withdraw from the National Board for Jurisdictional Awards. This secession will bring the Board's usefulness to an end.

The normal ups and downs in the industry from month to month during any given year are familiar to all. Building operations are extremely seasonal, partly because of weather but also partly because of habit and lack of effort to stabilize. "Each spring," says a recent report, "the field organizations are assembled, reach their maximum efficiency during the summer, and in the late fall disintegrate. Among the results of this practice are long periods of unemployment over the winter when skilled workmen drift into industries, delays and expense for repairs when new workmen are trained in the spring, and a high daily wage but an annual wage which is now always satisfactory." According to the Committee on Seasonal Operations in the Construction Industry, appointed by Secretary Hoover in 1923, following certain recommendations of the President's Conference on Unemployment, the building trades as a general rule are occupied wholly for only three to five months in the year and in practically all the cities studied show a large percentage of idleness in these trades not only from December to March, but in other months as well. "This burden of idleness," says the Committee, "falls most heavily not on the producers and distributors but on the employees and the public. Construction costs are high in part because of the seasonal hazard which affects each step of the construction process. . . ."

Fortunately, these seasonal fluctuations are to a large extent preventable. The exigencies of the war focussed attention on the practicability of winter construction, and since the War a great deal of scientific study has been given to the consideration of the extent to which the winter recession in building was due on the one hand to adverse weather conditions and on the other merely to tradition and inertia. The conclusion reached by the Hoover Committee already referred to was that while the winter let-up in operations was perhaps justified when methods of building were more primitive and knowledge of the characteristics of building materials less thorough, it is today, with modern machinery and processes and with advanced knowledge, rather the survival of custom. Certainly a rather extensive experience has shown that certain types of construction can be carried on even in northern cities with satisfaction as to quality and with little, if any, increase in cost. "Winter work," says the report, "is being done in some cases more cheaply than summer work and in others at an increase in cost which is slight compared with the advantages of holding down the

contractors' overhead expense by keeping his organization together, the shorter time that the owner's capital is tied up in the operation, and the earlier date at which occupancy is possible."

The recommendations of this Committee and the educational work carried on by the Department of Commerce and by various building organizations has already had a perceptible influence in regularizing the industry throughout the year. In each of the last three or four years, the winter lull in activity was much less significant than usual and there is basis for the hope that a permanent movement has been started. The more widespread diffusion of knowledge which will aid those who contemplate, or who may be encouraged to undertake, building in winter will do much to stabilize the construction industry and contribute to a reduction in construction costs.

Reducing Cyclical Fluctuations. More difficult than the task of lessening seasonal ups and downs in building activity is the problem of mitigating the cyclical fluctuations, those broader swings in the industry which reflect, if they do not cause, the recurring phases of the " cycle " in general business. Progress in the elimination of the building valleys and peaks, to the extent that these are the result of depressions and booms in general business, will depend largely upon success in stabilizing general economic conditions. Some progress has already been made as a result of the improvements in our banking system, the collection, interpretation, and dissemination of statistical data, and the development of the science of business forecasting. Much more, however, remains to be done. The application of this science of business forecasting to the building industry itself and the accumulation of more adequate data in regard to supply and demand before new enterprises are undertaken will assist in the ironing out of cyclical fluctuations in building, as will also the more systematic long-range planning of plant expansion by large industrial corporations. There is also merit in the suggestion made frequently in recent years that a reserve of public building should be accumulated in years of high activity to be thrown into the market when depression comes and private demands fall off. In this way public works would be used as a balance wheel to private industry. The widespread adoption of such a program is attended with certain difficulties, but the policy has already been tried on a small scale in some municipalities with success and is deserving of a much wider

trial. Certainly no pains should be spared to assure that the huge volume of construction on which general prosperity is so largely conditioned should be carried on at a fairly even rate throughout the years, not accentuating the ups and downs of general business and employment, but rather, if possible, serving to speed up activity when otherwise general business would be slack.

CHAPTER VI

THE COPPER INDUSTRY [1]

By F. E. Richter [2]

History. The copper industry as treated in this chapter will be taken to include those industrial processes which bring copper from the unmined state to the refined metal in the form of ingots, ingot bars, rods, or what not. The chapter will not deal with the fabrication of refined copper into wire, brass, or other manufactured forms, though it will naturally touch upon such integration as has taken place in a few concerns which, primarily copper producers, have become copper fabricators.

In the sense just indicated, the copper industry is not one of the outstanding industries of the country in capital used, number of employees, or money value of product. That the utility of the product is great goes without saying. The whole electrical industry is built on copper, and to enumerate the other industries in which copper is used would be to name practically all the peaceful arts and certainly could not omit the industry of war.

Space forbids any discussion of the ancient character of the industry and forbids more than passing reference even to its early history in this country. Suffice it to say that according to James Douglas, there was a copper mining enterprise in Massachusetts as early as 1640. In the two centuries that followed, copper deposits were discovered and copper was mined in most of the states on the Atlantic seaboard and in various other parts of what now comprises the continental United States. Until the middle

[1] Free use is made in this chapter, by permission of the publications concerned, of material in three articles by the writer: one in the February, 1916, issue of the *Quarterly Journal of Economics;* one in the February, 1927, issue of the same journal; and one in the January, 1923, issue of the *Harvard Business Review.*

[2] Economist, American Telephone and Telegraph Co.

of the 19th century, however, the United States cut no figure at all as a producer of copper. Wales and Cornwall were the copper centers of the world, though important production (for those days) was taking place in various countries of the Continent of Europe and elsewhere, notably in South America.

The copper industry of the United States may be said to have begun with the systematic exploitation of the copper deposits of the Keweenaw Peninsula, which juts out into Lake Superior from the upper peninsula of the state of Michigan. We say systematic because the existence of copper deposits in that region had been known to white men at least since the time of the Jesuit missionaries of the 17th century, who found the Indians regarding the great masses of copper which were occasionally discovered either as divinities or as divine gifts. In the year 1845, the Pittsburgh and Boston Mining Company put the first " Lake " copper on the market. The United States Geological Survey credits Michigan with an output of 13 tons of copper that year and the rest of the country with 99 tons, a total of 112 tons. Last year (1926) the country's output from domestic ore was about 870,000 tons, and in several years during the War the total rose above 900,000 tons. The following tables (I and II) show how the production of copper increased in the 80 years following 1845, and show that Michigan affords the only important exception to the statement that practically all the copper now produced in this country comes from west of the 105th meridian of longitude.

In the 25 years following the discovery of gold in California and the gold rush of the late forties, a number of copper deposits were discovered and exploited in a very small way in various western states, notably California and Arizona. The middle seventies opened up a new chapter in the history of the industry. From 1850 on Michigan output of copper had in most years completely overshadowed in importance the production of the rest of the country, especially after the great Calumet and Hecla mines were opened in the late sixties. In the first half of the decade of the seventies, for instance, Michigan accounted for 88 per cent of the country's output of copper; and the proportion was 84 per cent in the second half of the same decade. The year 1884 saw Michigan producing less than half of the country's output, and three years later Michigan was passed by Montana, which held first place until 1907, when Arizona became the principal copper producer,

TABLE I

Copper Production in the United States, 1866–1926

(Thousands of Tons)

Year	Quantity	Year	Quantity
1866	10	1897	247
1867	11	1898	263
1868	13	1899	284
1869	14	1900	303
1870	14	1901	301
1871	15	1902	330
1872	14	1903	349
1873	17	1904	406
1874	20	1905	444
1875	20	1906	459
1876	21	1907	434
1877	24	1908	471
1878	24	1909	546
1879	26	1910	540
1880	30	1911	549
1881	36	1912	622
1882	45	1913	612
1883	58	1914	575
1884	72	1915	694
1885	83	1916	964
1886	79	1917	943
1887	91	1918	954
1888	113	1919	643
1889	113	1920	605
1890	130	1921	253
1891	142	1922	475
1892	172	1923	717
1893	165	1924	817
1894	177	1925	837
1895	190	1926	871
1896	230		

a position which she has held almost without interruption ever since.

In 1871 the Clifton-Morenci district in eastern Arizona was opened up, followed by discoveries in 1874 at Globe, Ariz. Three years later, in 1877, came the first discoveries at the great camp of Bisbee, also in Arizona, and at about the same time there occurred the earliest operations in the remarkable camp of Jerome, Ariz. Most of these discoveries, chiefly because of lack of railroad facilities, did not result at once in copper production, but they

TABLE II

PRODUCTION OF COPPER IN THE UNITED STATES IN TONS

	1845	1865	1885	1905	1915	1925	PER CENT IN 1925
Alaska				2,450	35,347	36,102	4.3
Arizona . . .			11,353	113,427	216,234	361,327	43.1
California . .		1,800	234	8,349	18,829	23,472	2.8
Michigan . . .	13	7,179	36,074	115,144	119,478	69,015	8.2
Montana . . .			33,899	157,375	134,132	135,302	16.2
Nevada . . .					33,879	38,569	4.6
New Mexico . .				2,667	31,408	38,224	4.6
Utah				27,042	87,589	121,365	14.5
All others . .	99	541	1,378	17,938	17,109	14,059	1.7
Total . . .	112	9,520	82,938	444,392	694,005	837,435	100.0

gradually began to contribute to the state's output. Meanwhile, in 1875, some discoveries of rich silver ore were made at what had been a gold placer camp at Butte, Mont. Within a few years Butte, which soon became and long remained the greatest copper camp in the world, began systematically to turn out the red metal. The output of Butte and of the four Arizona camps that have been mentioned accounted for all but a small part of the increase, outside of Michigan, in the country's domestic supply of copper during the next twenty or twenty-five years. The output of Michigan increased slowly but rather steadily during the same period, as established mines increased production and a few new mines were opened. The deluge of copper from these three states was principally responsible for a decline in the price of the metal from around 23 cents in 1875 to an average for the year 1894 of less than 10 cents. And in 1895 the United States for the first time produced more than half of the world's copper, which she has continued to do ever since, except for the depression year 1921, when drastic curtailment took place.

For the copper industry, as for many others, the end of the 19th century witnessed the closing of one era and the opening of a new one in industrial organization. In the copper industry the movement was slower in gaining ground and made less progress on the whole than in various other industries. Of these matters much more will be said later. This much is mentioned here to indicate in passing only one of the aspects of the contrast between the

twenty years before 1895 and the twenty years after 1895, ending with the opening of the World War. Let us continue to confine ourselves at the present juncture strictly to the history of copper mining. The closing years of the century witnessed developments in California, Michigan, and Arizona (in the last-named state especially at Bisbee), which soon added substantially to the outputs of those states, principally through the Mountain Copper Company and other mines in California, the new Copper Range group of mines in Michigan, and the Calumet and Arizona group and the Shattuck-Arizona at Bisbee. These were to be quite overshadowed by the ultimate results of operations begun at about the same time in Bingham, Utah. From these operations finally sprang the huge Utah Copper Company, the first and the greatest of the group of domestic "porphyry coppers." This was important not only for the contribution which the Utah Copper itself has made to copper production, but because the mining and reduction methods developed in the exploitation of the low-grade deposits of the porphyries have brought about a revolution in the copper industry, adding hundreds of thousands of tons of copper to the annual production of the country and the world, both from the porphyries themselves and from low-grade ores in other mines. The development of these porphyries, in Utah, Nevada, Arizona, and New Mexico, was clearly the outstanding event of the first decade of the twentieth century. Between the close of that decade and the World War occurred the only other important exploitations of copper deposits that remain to be mentioned.

One of these new developments was in Alaska; three others were in Arizona. More or less desultory production of copper had been going on in Alaska for some years, principally in two coastal districts. An enormously rich deposit had been discovered one hundred miles inland, in the Copper River region, which only awaited transportation facilities to make it profitable. Guggenheim interests secured the mine. The Copper River and Northwestern Railroad was built to the mine in 1911, and the great Kennecott mine then began to ship its fabulously rich ore. As early as 1915 Alaska output had been raised to 70,000,000 lbs., as a result of Kennecott production. Near the Kennecott mine development work began in 1914 on the Mother Lode mine, and while for various reasons progress in exploitation of this deposit was much slower than in the case of Kennecott, Mother Lode is

now one of the larger producers of the country, turning out about 30,000,000 lbs. of copper a year from both high-grade and low-grade ores.

Two of the new developments in Arizona were in old settled producing camps; the other in a region which had been explored and been known as copper-bearing for half a century but which could not be exploited until twentieth-century metallurgical advances had made it economically possible to do so. In Bisbee, the old Copper Queen mine just before the War was beginning to develop a low-grade deposit in porphyritic rock on its property. As in the case of the Mother Lode, progress was made slowly until after the War, but during each of the last three years (1924–26), this Sacramento Hill deposit has yielded about 50,000,000 lbs. of copper. Meanwhile at the old camp of Jerome, where the rich United Verde mine had for a quarter-century been the only producing property of any consequence, a large mass of rich ore was discovered in 1914 and exploited by the United Verde Extension Mining Company. In three years this company was producing more than 63,000,000 lbs. of copper in a year. Not since 1917 has its output been this large, but with an output in 1926 of 43,000,000 lbs. it ranks among our largest producers. The third development in Arizona was the exploitation of a low-grade copper deposit at Ajo, in the southwestern part of the state, by the New Cornelia Copper Company, a subsidiary of the Calumet and Arizona. The engineers of the latter company had by 1913 " blocked out " ore reserves of sufficient size to justify its beginning operations on a low-grade deposit of oxides, carbonates, and sulfides and to justify building a railroad 45 miles in length and erecting a reduction plant, all in the midst of the desert. In 1926 this mine produced at a good profit, from ore yielding about 1 per cent, 82,000,000 lbs. of copper, 80 per cent more than its parent company, and took rank as the sixth largest producing mine in the United States.

We have now traced in rough outline the history of copper mining in this country, at least to the extent that we have indicated the main sources, and the magnitude of the growth in copper mine production in the last eighty years. Eight districts, each of which have produced more than 1,000,000,000 lbs. of copper from their earliest beginnings through 1925, have turned out nearly 30,000,000,000 lbs. of the metal, accounting for nearly five sixths

of the domestic copper output of the United States in the eighty-one years, 1845–1925. These districts are the following (production figures are in thousands of pounds):

District	State	Production Began	Output	Percentage of U. S.
Butte	Mont.	1868	8,917,000	24.9
Lake Superior . . .	Mich.	1845	7,483,000	20.9
Bisbee	Ariz.	1880	3,315,000	9.3
Bingham	Utah	1896	2,837,000	7.9
Globe-Miami	Ariz.	1881	2,432,000	6.8
Jerome	Ariz.	1883	1,880,000	5.2
Morenci-Metcalf . .	Ariz.	1873	1,658,000	4.6
Ely	Nev.	1908	1,067,000	3.0

In 1925, fifteen mines accounted for 83 per cent of the country's domestic copper output of that year. Five of these — the Ray and the Chino, two "porphyries" which have not yet been named in this chapter, the New Cornelia, Kennecott, and Mother Lode — were not in any of the eight districts just mentioned. The other ten, in the order of their output, were the Anaconda, Utah, Copper Queen, United Verde, Calumet and Hecla, Inspiration, Nevada Consolidated, Miami, Calumet and Arizona, and United Verde Extension.

Technology. In what has so far been written, practically all mention of intercorporate, industrial, and trade relationships has been omitted, in order to outline copper-mining history in the briefest possible manner. It is not yet the place to enter upon the question of industrial organization, for the developments in that field will best be understood if we sketch first some of the problems and methods of copper production. In short, something must now be said about the mining and metallurgy of copper.

With the exception of native copper deposits, such as those in the Lake Superior district, and native copper occurrences elsewhere, copper is typically found associated chemically with other elements. Imbedded in rock, sometimes in massive form, sometimes in strings or more or less finely disseminated, the ore (the metal or metallic compound) must typically be separated as well as possible after mining, from the rocky container or gangue, and then the copper must be separated chemically from its associated elements either by heat or by some leaching fluid. The process of recover-

ing the copper from the ore and bringing it to the form of metallic copper is known as reduction; and the problem of the metallurgist is to ascertain just which reduction process or processes are economically best suited to the ore or ores with which he has to deal. Since in this country, again with the partial exception of the Lake district, practically all copper comes on the market as electrolytic copper, there is no question, as there is in the case of lead and zinc, of varying reduction processes according as the final product will be one thing or another.

As in most other mineral industries, copper mining characteristically consists of underground operations; though to this there are important exceptions, such as the case of the Utah Copper Company which is tearing down a hill, and that of the Nevada Consolidated Copper Company, which gets a great part of its ore from an open pit. The occurrences of copper have the greatest possible variations from the finely disseminated low-grade ore of the huge blanket deposit of the Utah Copper Company to the relatively rich but highly irregular ore deposits at Bisbee, Ariz., or the complicated and faulted vein systems at Butte, or the wide and long but lean lodes at the Lake. The character of the occurrences has had much influence on the organization at the different camps, and the hundreds of varying problems of the mining engineers have had a substantial influence not only on costs but on both current and long-time production programs. In some camps the actual mining expense (including development costs) represents the largest single item in the cost of producing copper; in others it is a minor factor. In all camps naturally the substitution of mechanical power for man and horsepower has done much to reduce costs.

Aside from the revolutionary factor of the introduction of power drills a half century or so ago and of higher-powered explosives than black powder, at about the same time, the improvements in mining have been primarily in the better use of geological knowledge and in the development of methods of mining which were more economical than those previously used, either because they saved labor or because they enabled more ore to be extracted without endangering the physical safety of the miners. Not even the briefest discussion of developments in copper mining, however, would be complete without paying tribute to the enormous importance of churn drills and diamond drills in prospecting work. Before

drilling either from surface or from underground was resorted to, only outcrops of ore or geological probabilities indicated where pay ore was likely to be found, and the only way actually to find the ore was to mine for it at heavy cost; and then perhaps ore was not found! Drilling has been especially important where ore occurrences have been irregular, as at Bisbee, in determining not only the location but the grade, chemical composition, and general character of previously undiscovered ore. Above all, it has been important in the case of the low-grade disseminated ore mines, such as porphyries. The exploitation of these low-grade deposits, which have added so much to the world's supply of copper, has been possible only because well-conducted drilling campaigns on the deposits have established the extent and grade of the deposits, and have enabled plans to go forward not only for mining them but for the erection of reduction works to treat the huge tonnages of ore which were to be forthcoming.

Of all the important industrial metals mined in large quantities in this country, copper has the greatest value per pound. Chiefly because of this fact, copper ores are mined which on the average have a much lower metal content than lead or zinc ores, to say nothing of iron ores. In the year 1923, the 45,519,000 tons of copper ore mined had a copper content of only 719,000 tons, or only 1.58 per cent. This compares with a production of 40,361,000 gross tons of pig iron from 73,312,000 gross tons of iron ore, a yield of 55 per cent, or nearly 35 times the content of copper ore, although the price of copper is only about seven times that of pig iron.[1] Among the important producing states, the percentages of copper content ranged from .91 of 1 per cent in Utah to 5.88 per cent in Alaska. Practically all the copper ore, to be sure, yielded values in precious metals, but for all the copper mines the average value of the gold and silver content was only about $1\frac{1}{4}$ cents per pound of copper content. Forty or fifty years ago many a camp discarded copper ore with a higher copper content than is carried by all the ore now mined in that camp, or in the metallurgical processes wasted amounts of copper which were more than equivalent in yield percentages to present-day average yields of ore mined.

The achievements of the copper industry illustrated by some of the figures in the preceding paragraph have been made possible

[1] Corresponding yield figures for lead and zinc are not available.

by notable advances in every step of the metallurgical process, by steadily increasing coöperation between the metallurgical and mining departments of the industry, and by numerous economies coming from large-scale production, not the least of which are secured by continuous flow of the product through the works, especially in the pyrometallurgical stages. Large-scale operations have made possible and greatly facilitated metallurgical improvements.

Typical copper metallurgy for sulfide ores (that is, ores like chalcocite, bornite, covellite, enargite) consists of the following stages: dressing or concentration, roasting, smelting, and refining. (In the case of oxide ores, the concentration and roasting stages are omitted. There is no roasting of native ores, and the smelting and refining of these are hardly more than melting operations.) Dressing or concentration consists of crushing the ore and the gangue (the worthless rock containing the ore particles) into more or less fine particles and effecting as good a separation as possible between the ore and the gangue. Concentration, whether done in the forty-niner's pan or in old-style jigs, or with more modern dressing tables, or in flotation tanks, involves the use of gravity assisted artificially by agitation, generally in water. The lighter gangue runs off at the top while the heavier particles of ore sink; except that in the case of oil flotation the very finely crushed particles of ore adhere to the bubbles of the froth that is created in the mixture, and float off in the froth while the particles of gangue sink to the bottom of the tank. Concentration is resorted to as a first step in reduction because it is naturally desired to submit as small a volume of material as possible to the expensive fire processes of reduction. The fact that the melting points of most rocks that make up the gangues are higher than the melting points of the ore means, furthermore, that milling decreases the use of fuel in even greater ratio than is the volume of the material sent to the furnace.[1]

Roasting generally precedes smelting for sulfide ores for the two-fold purpose of driving off excess sulfur and effecting oxidation of the iron in the ore; the latter, in order that in the smelting furnace

[1] Oil or other flotation not only does this, but also saves copper which could not possibly be saved by water concentration, namely, the extremely fine particles of disseminated ore characteristic of the "porphyries" and of certain portions of the deposits of other mines.

the oxidized iron will combine more easily with the silica in the gangue, serving as a flux and reducing the consumption of fuel. The hot calcines from the roasting furnace go directly to the matting furnace, or first smelting operation, the products of which are matte and slag. Here again gravity comes into play. The liquid matte containing chiefly copper, sulfur, and iron, assaying about 40 to 50 per cent copper, is formed at the bottom of the furnace, while the slag, composed principally of silica, alumina, and other worthless materials, and very little copper, is lighter than the matte and floats above it as oil floats on water. The slag is tapped off at one place in the furnace wall and the matte at another, and the latter goes in its molten state to the converter to be blown up or " bessemerized " to blister copper, so-called because air bubbles escaping from the cooling pigs cause blisters on the surface. Pig copper is about 99 per cent pure. It goes to the anode refining furnace, the product of which, anodes, goes to the electrolytic bath. Electrolysis separates out the precious metals, which are recovered from the slime in the bottom of the bath; and the cathodes then go to the furnaces, where they are melted into the desired shapes, such as ingots, ingot bars, and rods.

Whether milling concentrates the ore in the ratio of 40 or 50 or 60 to 1, as in the case of low-grade Lake ores, or 15 or 20 to 1 in the case of finely disseminated sulfide ores, or in a ratio nearer to or even below 5 to 1, as in the case of some of the higher-grade sulfide ores, it is obvious that, other things being equal, transportation factors will call for the mill to be located at the mine or as close to the mine as is feasible. At the other extreme of the process, it is clear that as far as transportation costs go, it makes no difference where the refinery is located, since 99 per cent blister copper will pay no more freight than 99.9 per cent copper. In fact, it is cheaper to transport blister copper than it is to ship refinery products, since the latter include extracted gold and silver for which high express rates must be charged and which pay no extra freight at all as long as they are still imbedded in the blister copper. The smelter wherein the copper is brought from the stage of concentrates to that of blister copper, or the correspondingly refined stage, should normally be and generally is at no great distance from the mill, since its operations also represent a reduction in the volume of the value-bearing material of anywhere from 50 to 80 per cent or more. It is highly essential that all the operations

from roasting through the production of blister copper should take place in one plant. Continuity of operation in pyrometallurgical work, whereby the products of one operation are turned over to the next with the minimum loss of heat and at any rate without entirely cooling off, naturally means great economies in fuel, in time, and in floor space, as well as better metallurgical control.

Without any exception, the important American copper mines own their mills, and with few important exceptions the mills are located within a few miles of the mine; the location of the mills being influenced largely by suitability of the site for proper flow of materials, water supply, and easy access to transportation facilities. (Curiously enough, the two instances where mills are furthest away from large mines obtain in the cases where the ore tonnages are the greatest: namely, the Anaconda and the Utah companies. In each case, the heavy trainloads of ore shipments go over roads affiliated with the mining companies.) The ownership of mills is as far as some of the most important copper mines of the country go in integration, while, on the other hand, we find the Anaconda Copper Mining Company exemplifying practically the upper limit of vertical combination.

Industrial Organization. It may be of interest to trace the historical and economic reasons for the development of industrial organization in the copper industry. In the early days of copper mining at the Lake, all copper, whether in the form of masses of the native metal or of concentrates, left the Lake district to be smelted and refined, going to Detroit, Cleveland, Pittsburgh, or, in the earliest days, Boston and Baltimore. It was the rich Calumet and Hecla which was first able to have a smelter of its own, and even this did not come for a couple of decades after the mine was discovered. There were a few isolated furnaces in the early days, but apart from these the Quincy Mining Company is the only Lake company outside the Calumet and Hecla that has had a smelter of its own. Two other smelting works in the district owned jointly by some of the mining companies have reduced all the Lake copper not produced by the Calumet and the Quincy works.[1] Most of the Michigan mines have been producers on a relatively small scale.

[1] At the Lake, a smelter is also a refinery, since refining simply involves a second simple furnace operation — except to the extent that electrolytic refining is resorted to.

Furthermore, the copper-bearing material fed into the furnaces has averaged perhaps 60 per cent copper, so that Lake smelting works represented only small investments per ton of output in comparison to smelters elsewhere, and erection of individual smelting works by any but the largest producers in the district was out of the question. At the same time it was more feasible to ship fuel, by water or by rail, to the Michigan district and control the smelting process locally than to ship copper masses or concentrates away from the district. The Calumet and Hecla for a while owned works at Black Rock, near Buffalo, refining some of its product electrolytically, with energy from Niagara Falls, but later transferred its electrolytic refining to the Lake. In short, at the Lake we find only the Calumet and Hecla and the Quincy mines fully integrated through the refining stage, though various other companies are joint owners of smelting and refining works which treat the copper on toll for their shareholders and other organizations.

At Butte the history and evolution of organization have been on entirely different lines, as might have been expected from the utterly different character of the Butte camp. In the early eighties production came from a considerable number of rich mines, all found within an area of a few square miles. In the early days of the camp the ores were extremely rich, a fact which might have been expected to make concentration inadvisable. It was so necessary, however, to lessen the expense for fuel and flux that in many cases ores running over 10 per cent copper were milled. Huge losses of the metal resulted. Fuel, however, was dear, while copper was "the cheapest thing in Butte." Virtually every mine of any importance there soon had a mill of its own. Smelters were also soon erected. The first works at Anaconda were begun for the Anaconda mine in 1883, and counting these, a half dozen smelters, all but one erected by mining companies themselves, were in operation by the end of the eighties at or near Butte. At first only rich matte was produced, and this went to the Atlantic seaboard or to England to be refined. Gradually, converters were installed and blister copper turned out, and finally, in 1892, the Anaconda built an electrolytic refinery to treat part of its copper, the rest continuing to go, as it had for some years, to Baltimore. Early in the nineties, too, the Boston and Montana began work on its notable and complete smelting and refining plant at Great Falls. These were the first instances in the country of complete

integration upward through the electrolytic stage. In time the Amalgamated Copper Co. came to control, and later the Anaconda to own, all but a very few of the important producing mines at Butte. All Anaconda ore then went, as it now goes, to the monster Washoe works at Anaconda. By that time, however, electrolysis was no longer carried on at Anaconda, but in the East at Perth Amboy, N. J. and at Great Falls, Mont., where hydroelectric power was available.

The character of the ore deposits and their occurrences at Butte had a definite influence in encouraging the concentration of control of productive territory that finally came about. The camp is a relatively small one and within the ore-bearing district is a highly complicated system of veins with many faults, which, given the mining law as it existed, led to an interminable series of costly law suits to determine ownership of veins. Only companies operating with great profit on rich ground could have stood them. Obviously, united control meant not only the avoidance of law suits, but much more economical mining operations and more economical practices in the reduction processes. The inevitable therefore came about.

The Anaconda Copper Mining Company. This is a fitting place to indicate the organization of the Anaconda Copper Mining Company, as it has finally evolved into the most completely integrated concern with the most far-flung operations, in the nonferrous metal industries of the United States. In the year 1926, the reduction works at Anaconda produced, from the company's ores — transported over the affiliated Butte, Anaconda, and Pacific Railway — 254,302,568 lbs. of copper, 8,226,724 oz. of silver, 31,764 oz. of gold, and, as a by-product of copper-smelting operations, 6,864,718 lbs. of arsenic. A small amount of additional copper was produced from other ores. There were concentrated at these works 478,994 tons of zinc ore, most of which was purchased from other producers in or around Butte, including the controlled and leased Butte Copper and Zinc Co., though some came from the company's own mines. A sulfuric acid plant, making acid from the sulfur in the furnace fumes, supplied acid for metallurgical uses, and for making fertilizer, also at Anaconda, from phosphate rock mined by the company in Idaho. The coal used at Anaconda came from the company's mines near by and in Wyoming, which supplied coal for other operations also and sold coal to outsiders. The mines at Butte

were timbered with the company's own timber, cut in its own sawmill. Up at Great Falls, the electrolytic refinery turned out 243,285,551 lbs. of cathode copper, melting most of this into shapes for shipment elsewhere or for rolling right there; for the rod and wire mill rolled some 168,000,000 lbs. of copper into wire rods, drawing some 41,500,000 lbs. of these into wire, and shipping nearly a third of the rods to a wire plant of the controlled American Brass Company.

Down in New Jersey, the big works at Raritan refined for Anaconda subsidiaries, affiliates, and others, 393,201,524 lbs. of copper, turning out also 21,735,903 oz. of silver, 132,335 oz. of gold, and various amounts of nickel, platinum, selenium, tellurium, and palladium, as well as copper sulfate. At Rutherford, in the same state, a plant made copper-clad shingles. In the near-by state of Connecticut, and in New York, Wisconsin, and Canada, the American Brass Company, the greatest consumer and fabricator of copper in the world, turned out copper, brass, and other products to an amount of more than 686,000,000 lbs., of which presumably fully two thirds was copper.

The wholly owned International Smelting Company had at Tooele, Utah, a copper smelter, a large lead refinery, a zinc concentrator, and a railway company, and at Miami, Ariz., owned a much larger copper smelter and refinery, where it treated the ores and concentrates of the Inspiration Consolidated Copper Co. (about 30 per cent of whose stock the Anaconda owns) as well as those of the neighboring Miami Copper Co., the Old Dominion at Globe, and doubtless other custom material. Plants of wholly owned subsidiaries in Indiana and Ohio produced some 163,000,000 lbs. of lead, over 8,300,000 oz. of silver, some gold, white lead, and more than 40,000,000 lbs. of zinc oxide, from the Anaconda's own or purchased material. An oil company in California, jointly owned by the Anaconda and the Inspiration, produced 301,454 barrels of oil, some of which at least was used as fuel "within the family." There were a few other odds and ends of enterprises in the United States.

The first of its foreign properties Anaconda secured at the time of the dissolution of the Amalgamated Copper Company and the transfer of its assets to the Anaconda. That was some 30,000-odd shares of stock of the Greene Cananea Copper Co. of Mexico. This is of quite minor importance in comparison with the foreign

assets since acquired. Of these, of course the most notable is a controlling interest, consisting of 2,200,000 shares, in the Chile Copper Co., controlling the operations of the great mine of the Chile Exploration Co. at Chuquicamata, Chile, third in size of output among the producing copper mines of the world in 1926, turning out 220,138,465 lbs. of electrolytic copper. Also in Chile are the partially developed but non-operating properties of the subsidiary Santiago Mining Co., and operations of the wholly owned Andes Copper Mining Co., at Potrerillos, which for a number of years has been developing its mine and constructing a metallurgical plant, and which produced its first copper in January, 1927. Finally, in 1926, the Anaconda, through a subsidiary, secured a majority interest in the Giesche Spolka Akcyjna, which owns deposits of zinc ore and coal in Polish Silesia.

Truly an international organization, this. And, of course, it need hardly be said that it has its efficient selling organization — of which more later — to sell copper and zinc that go through its hands and are not consumed by the American Brass Co. The Anaconda represents the extreme limit of both horizontal and vertical combination in the copper industry. Until after the War its expansion came almost entirely either out of profits or through the issuance of stock, for cash or in exchange for other stock or physical property. The development of the Andes property and the acquisitions of control of the American Brass Co. and the Chile Copper Co., however, were made possible by sales of large bond issues. On December 31, 1926, there was capital stock outstanding of a par value of $150,000,000 and the company also had a funded debt (including debentures of the Andes Copper Mining Company) of more than $214,000,000.

The Kennecott Group. The most important purely copper-producing horizontal combination is that of Anaconda's principal rival, the so-called Kennecott group. The mines in this group have, ever since they became important producers, all been under at least affiliated control, represented by the Guggenheim-Hayden-Stone interests. The principal units of the group are the Kennecott Copper Corporation and the Mother Lode Coalition Mines Co. of Alaska, the Utah Copper Co. of Utah, the Nevada Consolidated Copper Co. of Nevada, the Ray and Chino mines of Arizona and New Mexico, respectively, and the Braden Copper Co. of Chile. The Kennecott mine was originally a

producer almost entirely from extremely high grade ore, and the Mother Lode mine secures a substantial part of its output from very rich ore. Each of the other mines in the group works a typically low-grade blanket deposit of disseminated ore. Their mining problems are different, but the problems of reduction are essentially similar. In no case, except Nevada Consolidated, has any of the mines in this country operated a smelter, each of them being provided only with a mill and sending its ores and concentrates to one or another smelter of the American Smelting and Refining Co., which also refines their products. The Smelting Company, of course, has also been under Guggenheim control. In 1926, the total copper production of the mines in this group amounted to no less than 713,000,000 pounds. In the case of every one of these properties, original development and some of the expansion have been made possible by bond or note as well as stock financing. The huge blanket deposits of the low-grade mines were "prospected" with drills, which gave the engineers data as to tonnage and grade of ore, on the basis of which they could plan for plants of certain capacity and immediately finance the construction of at least the first unit of these plants. This is an entirely different procedure from the old one, characteristic of mining operations down the ages, of development and prospecting literally and figuratively in the dark, and gradual expansion largely through profits.

The actual corporate organization of the group is as follows: Kennecott owns practically all the shares of Utah Copper, holds a minority interest in Mother Lode, and owns all the shares of Braden. Utah has a majority interest in Nevada Consolidated, which in turn owns practically all the shares of Ray Consolidated, and at present writing is endeavoring to secure all of the shares, whereupon the Ray Consolidated would be dissolved. Ray a few years ago, through the exchange of stock, secured all the stock of the Chino Copper Co. operating in New Mexico, and that corporation went out of existence. Thus we have in the one group, combination and control through ownership of physical property, ownership of all the stock of another corporation, majority stock control, and minority stock ownership. Each of the companies has a short-line railroad over which its ores or concentrates are shipped. The Kennecott was from the beginning such a big profit maker that it was not unnatural to make it the parent com-

pany for the Braden; and then later when Kennecott's high grade ore reserves had become substantially reduced, the acquisition of control of the long-lived Utah by an exchange of shares gave it an asset of much more assured permanency than its own physical assets. Similarly, the Utah has always been more prosperous than the Nevada, and on the whole the Nevada more prosperous than Ray or Chino.

Phelps Dodge; Calumet and Hecla. Before giving our attention to the American Smelting and Refining Company, as might seem logical at this point, it might be better to complete what there is to say about combinations of mining companies as such. In the Southwest is that other important combination of copper producers, the Phelps Dodge Corporation. Fifty years ago the then members of Phelps Dodge and Co. were dealers in and fabricators of non-ferrous metals. They became interested in the mining of copper through the purchase of the old Copper Queen down at Bisbee, Arizona; and the Copper Queen mine was operated by a close corporation until it was taken over by the Phelps Dodge Corporation. The principal operations of the Phelps Dodge Corporation are at Bisbee; at Clifton-Morenci, where the property of the Arizona Copper Co. was acquired some years ago; at Nacozari, Mexico, where copper mining operations are carried on through the Moctezuma Copper Co.; at Stag Canyon, New Mexico, where the corporation owns coal mines and coke furnaces to furnish fuel for other Phelps Dodge properties; and at Douglas, Arizona, where are found the corporation's principal reduction works. The corporation is thus integrated from the stage of owning copper mines and coal mines through the stage of producing, at Bisbee and at Clifton, blister copper which it sends east for refining. It does not refine its own copper, but sells its copper as well as the copper of its neighbor at Bisbee, the Calumet and Arizona Mining Company, and also the copper of the Old Dominion Company at Globe, which is under the control of friendly interests. In 1926, Phelps Dodge mines produced 197,849,933 lbs. of copper, some by-product silver and gold, and also a few million pounds of lead.

The first "giant" in the copper industry in this country was, of course, the Calumet and Hecla, formed in the early seventies as a consolidation of two affiliated mines, the Calumet and the Hecla. It contented itself for more than thirty years with operating simply

on the conglomerate lode which ran through its property and which had yielded it such fabulous profits. As previously indicated, it was the first of the Michigan mines to have a smelter of its own, and since this step was taken, it has been completely integrated as a copper producer through the refining stage. In the first decade of the twentieth century, the Calumet and Hecla began to buy into and finally to control a number of mines operating on amygdaloid lodes in neighboring or more distant territory, and some of these properties have been completely merged with the parent company. Unity of operation has to a certain extent been possible in the case of these acquired properties, though some of them have represented separate operations which were of benefit to the Calumet chiefly to the extent that they fed material to the Calumet mills and furnaces. Calumet and Hecla has always sold its own copper either through its own officers, or in the early days through the famous Charles Raht, who was for decades the selling agent of the Calumet and Hecla.

The American Smelting and Refining Company. The foregoing represent all the important horizontal and vertical combinations in the copper industry of this country, with the outstanding exception of the American Smelting and Refining Co. This organization is the greatest refiner and marketer of non-ferrous metals in the world. Its report for 1926 discloses the fact that in that year there were turned out of its plants 525,897 tons of copper, 469,607 tons of lead, 48,723 tons of zinc, 85,482,438 oz. of silver, and 1,634,158 oz. of gold, in addition to small amounts of numerous minor metals. The company was incorporated in April, 1899, as a combination primarily of trans-Mississippi lead smelters. There remained outside of the combination the important lead- and copper-smelting concern of M. Guggenheim's Sons. They were brought in in 1901, and five of the Guggenheims were immediately elected to the Board of Directors. Since then the company has been a Guggenheim organization, and has been a notable factor in the copper industry of the country, increasing in importance as time went on. This was not because of its ownership of copper mines, for its own mine production of copper has always been relatively unimportant, chiefly a by-product of lead mining, and has come principally from its Mexican properties. The importance of the company in the copper world has been due chiefly to three things: (1) its great and increasing copper smelting and

refining capacity; (2) the fact that for many years it sold practically all the copper it refined; and (3) the control or influence exerted by the Guggenheim interests in what has already been described as the Kennecott group, as well as in the Chile Copper Company until that was sold to Anaconda. Even now that it has turned over its selling of most of the copper it refines (other than the product of its own mines) to Guggenheim Brothers, the identity of effective control of these two organizations actually makes for little difference in the effect on the copper market.

The company owns copper smelters at Maurer and Carteret, N. J.; El Paso, Texas; Hayden, Ariz.; Garfield, Utah; and Tacoma, Wash. Its refineries are at Maurer, Carteret, Baltimore, and Tacoma, the Baltimore refinery having the largest capacity of any in the world, and in addition doing some fabricating of copper. The company owns some substantial coal mines and coke plants and a fleet of steamships for carrying products from the Gulf of Mexico to New York Harbor. As is clear from this recital, it stands second only to the Anaconda in point of integration in the copper industry, and actually handles in its refining plants more copper each year than does the Anaconda or any other organization in the world. The greater part of its copper, as has been indicated, comes from mines between which and the smelting company there is community of interest, but it refines a substantial amount of the red metal other than the product of these mines or of its own.

There are two refineries in the United States which are not owned by any copper mining companies, as is the Michigan Smelting Co., and are not integral parts of copper-producing organizations, like the Anaconda refineries. One is the Nichols Copper Co. of Laurel Hill, L. I., whose works have been in operation for decades purely as a custom smelter and refinery. For many years its principal customer was the Phelps Dodge Corporation, and at that time it sold little or no copper. Now it refines copper for various domestic and foreign corporations (principally the latter) and sells a large part of the copper that goes through its plant. The other refinery is that of the American Metal Co. at Chrome, N. J., an important selling organization which, however, owns no American copper-mining properties.

This completes, except for one item, what will be said about the organization of the copper industry. The rather cursory survey

has by necessity been limited to the principal organizations. By inference, the reader may have gathered that there is little to say about the others; and this inference would be true. Aside from the organizations that have been mentioned, including the subsidiaries of the Anaconda, the only smelters in the United States operating on primary copper are one in California, two in Tennessee, and three or four in Arizona; these last including the smelters of the United Verde at Clarkdale, the United Verde Extension at Clemenceau, the Magma Copper Company at Superior, and, when it is operating, a smelter at Humboldt. Every copper refinery in the United States has already been mentioned. It should be noted right at this point that, while the smelter production of copper from domestic mines is running in the neighborhood of 850,000 to 875,000 tons a year, and at its peak during the war was 964,000 tons, the refining capacity of the country, including the Lake works, is not far from 1,700,000 tons, or nearly twice the domestic mine output. There is surplus refining capacity, though not to the extent that these figures alone would indicate, partly because much foreign copper is refined and partly because practical capacity of course never equals theoretical capacity over a period of time.

Foreign Copper. There has never been any one organization in the American copper industry whose position approached the monopolistic in character since the Far Western mines were opened in the seventies and eighties. Prior to that time, the Calumet and Hecla, not only because of its own production, but because it managed a Lake copper pool, came close to being a monopoly, aided, for a little while, by a tariff on copper imports. Its quasi-monopolistic position was short-lived, and the flood of copper of the late seventies and the eighties made the tariff utterly useless, leading to its repeal in 1894. From the late eighties on there have always been three or four or five outstanding organizations. These larger organizations and various smaller ones have at most times been in a position to push production and enlarge output because there has always been a sufficient amount of copper produced at a comfortable margin of profit above expenses (especially if depletion be not included among expenses), so that there has always been an urge to increase production even when price movements and common sense seemed to indicate the desirability of curtailment. In the sixty years since 1865 there have been only eight

years, other than 1917, 1919, 1920, and 1921, in which copper production did not increase over the preceding year, despite notoriously wide fluctuations in copper prices over that whole period. Even since the War, with copper prices from 1921 on averaging below the average levels for the fifteen years before the War, while general wholesale commodity prices were far above pre-war levels, production has expanded year by year until 1927. One complicating factor in the situation is that involved in the imports and exports of copper, which is the one item referred to above which must still be dealt with in the consideration of the organization of the industry.

It has been brought out, to be sure, that American interests have control of a very large amount of foreign copper output. To mention only the principal ones, the great Chile Copper Co., it will be recalled, was originally under Guggenheim control and is now controlled by the Anaconda; Kennecott owns the Braden property in Chile; the Cerro de Pasco Copper Corporation, operating in Peru, is also controlled by American capital and capitalists. Phelps Dodge and American Smelting own copper mines in Mexico. The Anaconda owns the Andes Copper Co. in Chile, which has just begun to produce. Even before American capitalists began to invest in and develop foreign copper properties, however, indeed way back in the middle nineteenth century, relatively large amounts of copper were beginning to come to this country for reduction and treatment. As our domestic mining industry increased in importance, and our reduction works in efficiency, British reduction works lost ground steadily, relatively or absolutely, or both. The flow of copper to this country began to increase. With our own domestic production rapidly mounting, we began to play an increasingly important rôle as an exporter of copper, and with the perfection of copper refining, especially by means of electrolysis, the copper output of our refineries came to be the standard of excellence the world over, and New York quite displaced London as the principal copper market of the world. The figures (in millions of pounds) tabulated at the top of the next page will give some idea of the relative importance of our import and export trade in copper.

The significance of these figures lies in two directions. In the first place, they indicate the enormous volume of copper that comes to this country, most of it for refining *and all for sale* (throwing

(1) Year	(2) Domestic Output	(3) Imports	(4) Exports	(5) Net Exports	(6) Per Cent of (4) to (3) Plus (2)
1906–15 (Ave.)	1100	314	703	389	50
1916	1928	462	784	322	33
1917	1886	556	1126	570	46
1918	1909	576	744	168	30
1919	1286	429	516	87	30
1920	1209	486	623	137	37
1921	506	350	628	278	73
1922	950	541	743	202	50
1923	1435	676	829	153	39
1924	1634	769	1117	348	46
1925	1675	653	1082	429	46
1926	1738	778	965	187	38

light on the use of some of the apparent excess refining capacity above domestic production referred to a few pages back). In the second place, they show clearly that the United States is typically a large net exporter of copper. In other words, copper, like so many others of our raw materials, is produced in such volume each year as to have its price determined on an international market, and by factors of demand and supply that are international in scope. More than one half of the world's copper is produced from American mines; between two thirds and three fourths of the world's copper is produced and sold under American control. Probably less than half of the world's consumption of virgin copper is ordinarily accounted for by uses in this country. With this situation and with the industry organized as previously described, it is clear why both in domestic and in foreign markets there is keenly competitive selling of copper. This leads to the final sections of this chapter — namely, the discussion of the marketing of copper in its various stages, and copper prices.

The Copper Market. In the days before the introduction of the electrolytic process of refining copper, the refined metal, a product entirely of furnace work, was far from being the homogeneous material that it now is. Today refined copper is one of the most homogeneous of metals. There are, to be sure, certain differences between Lake copper and electrolytic copper, but the different brands of electrolytic are exceedingly uniform. Figures of the U. S. Geological Survey for 1925 indicate that refining plants in the United States turned out in that year 1,025,000 tons of primary

or virgin electrolytic copper, and only 69,000 tons of Lake copper, and about 8000 tons of casting and best selected copper. These figures, of course, cover metal from both domestic and foreign sources and indicate the great predominance of electrolytic copper in the total. Lake copper has always sold and still sells at a premium generally amounting to a small fraction of a cent a pound over electrolytic, simply because its properties make it particularly desirable for a few restricted uses. Casting or best selected copper sells at a discount from electrolytic.

The uniformity of electrolytic copper has been perhaps the principal factor which has brought about the simplicity of organization of the market for copper. It can be said indeed that the market place for the metal is for all practical purposes the telephone, since undoubtedly much the greater part of the metal marketed is sold over the wire, largely in New York City. Buyers shop around over the telephone and sellers may often call up the principal buyers in efforts to dispose of their product. Not only does the uniformity of the product, with the slight differences between the various brands, facilitate this, but also the fact that selling is concentrated in a relatively small number of hands, as it has been during practically all of the last 60 years. Furthermore, a substantial amount of the immediate domestic consumption is also confined to a relatively small number of primary users, though, to be sure, the buyers as a group are rather more numerous than the sellers. Including the American Brass Co., which does not enter the market as do other consumers, but gets its copper through the parent organization, the Anaconda, the dozen leading buyers probably represent easily three fourths of the domestic consumption of the metal. The upper half of this list doubtless accounts for more than half of total domestic consumption.

If space permitted, it would be interesting to trace the historical development of the organization of the primary raw copper market. This will be impossible, and we can only indicate the situation as it exists today.

The American Bureau of Metal Statistics, in its Year Book for 1926, lists seventeen "principal sellers of copper in the United States." Of these fifteen, a half dozen interests overshadow all the others, as from four to six organizations have done for the last three decades. These are the Guggenheim Brothers, and the

allied American Smelting and Refining Company; Metals Sales Corporation (Anaconda), and the United Metals Selling Company (also an Anaconda organization which, however, does not sell copper in the domestic market); Phelps Dodge Corporation; Calumet and Hecla; American Metal Co.; and the Nichols Copper Co.

The selling agencies[1] receive for distribution four streams of primary copper:

(1) Copper from their own mines;

(2) Various forms of unrefined copper which refiners have bought outright, at figures based generally on current prices as published in the Engineering and Mining Journal;

(3) Copper sold for producers, on commission, on exclusive long-term contracts;

(4) Copper sold for producers, on commission, on orders covering specific quantities of the metal.

The chief causes determining the choice by producers of selling agents have been the following:

(1) Identical or allied control;

(2) The fact that the selling agent has previously smelted and refined the copper or is identified or affiliated with the refiner of the copper;

(3) The fact that the seller has financed or otherwise aided the producer;

(4) Friendly relationships, without actual financial alliance;

(5) Sundry business reasons, such as particular satisfaction with selling policies and results.

The great bulk of the copper sold by these agencies for others than themselves is sold under terms of long-time contracts with mining companies; much of the rest represents copper purchased in one stage or another of reduction. Occasionally sales contracts giving the producer control over the time and prices at which his copper may be sold are made, but these generally cover specific transactions and are not long-term agreements.

With conditions of both sales and consumption what they are, the producers and their sales agents have in general eschewed dealers or "second hands" and dealt directly with primary consumers. This is not to say that dealers do not exist or that they must rely solely on secondary or scrap copper for the means of

[1] Here I adapt from my article in the *Harvard Business Review* of January, 1923.

trading. From time to time, producing interests get rid of some of their copper to dealers, and at times, of course, overbought consumers find it convenient to unload a surplus on dealers, whose copper is frequently a real menace in a sensitive, thin market, and may at times for brief periods be price-determining. As for exchange dealings, while copper is among the commodities on the list of the New York Metal Exchange, the Exchange is but a nominal market for the red metal, lacking completely as it does the support of producers and of most sellers of copper.

As has previously been indicated, the copper industry has for decades been characterized by the keenest sort of competition for its product, not only in the domestic market but in the international market. Combination and affiliation have done little or nothing to reduce competition; they have simply assured that the principal competition would be between the giants of the industry. This competition and the urge to increase production which has characterized the industry have frequently led to sharp declines in prices of the metal. Foreign consumers have seemed to be able to take better advantage of this than have domestic consumers. Before the War at least a half dozen selling agencies had affiliations or agents abroad through whom they placed export sales, in competition not only with one another but with non-American copper. In December, 1918, the Copper Export Association, Inc., was formed under the provisions of the Webb Export Act, to endeavor to sell copper abroad to better advantage than had previously been the case. Some fifteen or twenty of the principal American producers took membership in this Association, which represented control in one form or another of about 80 per cent to 90 per cent of the primary copper in the New York market. Members agreed to sell all of their export copper through the Association. The Association rode through the difficult times of 1919 to 1922, when the former belligerents were dumping enormous tonnages of copper and brass on the market in competition with current production. Later, however, various factors caused some of the principal members to withdraw from the Association and to resume once more selling their own export copper. In view of the exceptional character of the period of the Association's operations, it is difficult to judge how much benefit American copper interests secured therefrom.

In October, 1926, Copper Exporters, Inc., was formed under the

provisions of the Webb-Pomerene Act. This organization comprised not only most of the principal producers and sellers of copper in the United States but also some of the principal foreign copper companies, and a few of the leading European dealers in copper. The expressed purpose of the organization was to stabilize the price of copper in foreign countries by eliminating speculation as far as possible, and by endeavoring to bring about in Europe a situation more nearly similar to that which had prevailed for years in this country — namely, that practically all of the copper should pass directly from the hands of producers or their selling agents to those of consumers, instead of going through second hands. Not enough time has yet elapsed to indicate clearly the probable ultimate degree of success of this organization.

Aside from these two export associations, the Lake pool of the seventies and early eighties, and a temporary coöperation on the part of the Lake and Butte to defend American copper producers' interests after the failure of the Secretan syndicate in the late eighties, there have been only two other instances of coöperation in the copper industry comparable with trade associations or other coöperative activities in other industries. During the five years just preceding the outbreak of the World War, there was in existence the Copper Producers' Association, which secured and reported each month statistics of the output of marketable copper by the regular primary copper-refining plants in the United States, and also the stocks of marketable copper on hand on the first day of each month. Since the figures were those of refining plants and of refined copper, they referred to all copper and not merely to domestic mine output. The statistics of this association were the only ones ever compiled by the copper industry as such, and immediately upon the outbreak of the World War and the demoralization of the copper market incident thereto, the gathering and publication of the statistics was discontinued. The other instance of coöperation within the industry is found in the organization in 1919 of the Copper and Brass Research Association, an organization composed not only of raw copper producers but of copper fabricators, whose purpose it was and is to call attention to the various uses of copper, and by advertising the merits of the metal to enlarge its consumption.

No official statistics of the industry other than those of the Copper Producers' Association were available either to the industry

itself or to the public until the formation of the American Bureau of Metal Statistics in 1920. This organization makes available each month figures of domestic mine output, total refinery output, stocks of copper in the hands of North and South American refiners, and various other figures of its own collection or from governmental sources, and thus enables the industry to secure a picture of conditions which previously it had never had at its command, although trade papers, notably the Engineering and Mining Journal, had done what they could to compile statistical and other information about current developments.

A few words should be said about the consumption of copper. For the best statistics and estimates in this field, we are again indebted to the American Bureau of Metal Statistics. The following figures, in short tons, give the Bureau's estimates of copper consumption, by principal uses or industries, since 1923:

	1923–1925 (Ave.)	1926
Electrical Manufactures [a]	185,900	201,000
Automobiles [b]	101,300	102,800
Light and Power Lines [c]	95,300	117,000
Telephones and Telegraphs	80,300	90,000
Wire and Rods [d]	57,500	74,000
Buildings [e]	41,700	50,200
Bearings and Bushings	36,900	38,000
Valves and Pipe Fittings	21,700	26,000
Other Domestic Uses	105,100	141,700
Manufactures for Export	54,200	49,900
Total	779,900	890,600
Pounds per capita	13.76	15.13

[a] Exclusive of manufactures for telephones and telegraph purposes.
[b] Not including electrical manufactures.
[c] Transmission and distribution wire and bus bars.
[d] Not elsewhere specified.
[e] Not including electrical generators, motors, etc.

It is worth while here to give the statistics of the U. S. Geological Survey, showing the percentages of refined copper cast in different forms in the United States in 1925. These are as follows:

Form	*Percentage*
Wire Bars	61.3
Ingots	12.1
Cakes	11.3
Cathodes	10.5
Other Forms	4.8
Total	100.0

The use of copper for transmission of electrical energy, not only in the form of wire but in other forms, accounts for the greater part of the use of wire bars. Ingots are used primarily in the manufacture of brass. Cakes and cathodes go into miscellaneous uses.

The Bureau of Mines has for a number of years collected figures of the amount of secondary or scrap copper refined in the United States. For 1925 the recovery is given as no less than 840,000,000 pounds; the average for the 10 years ending 1925 being about 700,000,000 pounds. It should be noted, however, that much of this (perhaps 260,000,000 pounds in 1925) represents fabricators' scrap collected in the manufacturing processes. The rest (580,000,000 pounds in 1925) is said to represent the salvaging and reuse of copper fabricated some time previously. This is the equivalent of the combined outputs in 1925 of the Anaconda, Utah Copper, and Calumet and Hecla, and makes a notable addition to the supply of copper available from primary sources, or virgin copper. Scrap copper is a much larger item in the total supply of the red metal than is scrap lead or scrap zinc in the supplies of these metals. This chapter aims to deal only with the production and sale of new copper, but at least this much mention of the importance of scrap copper was necessary, even though its uses, refining, and marketing are generally other than those of new copper.

The Price of Copper. As is well known, copper is one of the commodities whose recent price level has not only been well below the general commodity price level, in relation to pre-War conditions, but has actually been below average pre-War levels. The rate of increase both of refinery production of virgin copper and of scrap recovery has kept ahead of the rate of increase of consumption and exports, rapid though the latter has been. Table III shows the annual average price of copper from 1866, just after the discovery of the Calumet and Hecla, through 1926.[1] Three major movements of copper prices are visible. The first covers nearly thirty years, those three decades in which first Michigan and then the bonanza mines west of the Mississippi were pouring their floods of copper on the market and were steadily lowering unit costs of production through improved technical processes. The next period (nearly a quarter-century) closes with the Armistice

[1] The figures are from "Mineral Industry" and the Engineering and Mining Journal. They represent Lake copper through 1898 and electrolytic copper thereafter.

TABLE III

COPPER PRICES

(Cents per Pound)

YEAR	PRICE	YEAR	PRICE
1866	$31\frac{3}{4}$	1897	11.3
1867	$25\frac{1}{8}$	1898	12.0
1868	$23\frac{5}{8}$	1899	16.8
1869	$23\frac{3}{8}$	1900	16.2
1870	$20\frac{5}{8}$	1901	16.1
1871	$22\frac{5}{8}$	1902	11.6
1872	33	1903	13.2
1873	29	1904	12.8
1874	$23\frac{1}{4}$	1905	15.6
1875	$22\frac{1}{2}$	1906	19.3
1876	21	1907	20.0
1877	$18\frac{5}{8}$	1908	13.2
1878	$16\frac{1}{2}$	1909	13.0
1879	$17\frac{1}{8}$	1910	12.7
1880	$20\frac{1}{8}$	1911	12.4
1881	$18\frac{1}{8}$	1912	16.3
1882	$18\frac{1}{2}$	1913	15.3
1883	$15\frac{7}{8}$	1914	13.6
1884	$13\frac{7}{8}$	1915	17.3
1885	$11\frac{1}{8}$	1916	27.2
1886	11	1917	27.2
1887	$11\frac{1}{4}$	1918	24.6
1888	$16\frac{5}{8}$	1919	18.7
1889	$13\frac{3}{4}$	1920	17.5
1890	$15\frac{3}{4}$	1921	12.5
1891	$12\frac{7}{8}$	1922	13.4
1892	$11\frac{1}{4}$	1923	14.4
1893	10.8	1924	13.3
1894	9.5	1925	14.0
1895	10.8	1926	13.8
1896	10.9		

and is a period in which the trend of copper prices was upward. Each major peak of prices and each low point in this period was higher than its predecessors. The third period is not yet a decade in length. It includes the terrible drop in copper prices after the Armistice and the settling down of prices on a level below 15 cents a pound from 1921 on.

It is a curious triple coincidence that copper has the greatest electrical conductivity per unit of cross-section of any non-precious metal, that the electrical age of the world should have

really begun in the last quarter of the nineteenth century, and that the greatest discoveries of copper mines that the world had ever known, outside of Europe, should, with the exception of the Calumet and Hecla, all have taken place in the same quarter-century. But it is not a coincidence that the nineties witnessed the beginnings of electric street railways, the opening of a long-distance telephone line from New York to Chicago over copper wire, the formation of the General Electric Co., and an upturn in the price trend of copper. Other factors, such as a great increase in mercantile shipbuilding, the rise of the new German and American navies, increased armaments generally, and war, helped to augment the demand for copper in the twenty years preceding the outbreak of the World War. But the progress of the electrical industry in all its branches became increasingly the dominating factor in copper consumption. The table a few pages back, showing consumption statistics and the forms in which refined copper is cast, gives unmistakable testimony to this. Copper prices accompanied the general commodity price level upward in the twenty-odd years following the middle nineties. In the face of the accelerating use of electrical energy in the last ten years, why has copper fallen so much further than many other commodities since 1919 or 1920?

The answer must be and is found in the conditions of supply. For some years after military operations ceased, of course, the belligerents, as already indicated, were gradually disposing of hundreds of millions of pounds of copper, raw and fabricated, onto a market which would have been weak even without that, merely because the consumption of copper had dropped from the extremely high level forced by military use to a peace-time demand, which, because of impoverishment of many countries, was well below normal. In the last few years, government dumpings have not been a factor of any consequence. The answer to the question as to the low price of copper is to be found in other directions.

Ever since 1870, much the greater part of the copper output of the United States has come from a relatively few mines. This is tending to be increasingly the case. What is more important is that a steadily increasing part of our copper is coming from deposits whose very existence as profitable enterprises depends on large-scale production, and which have been able to effect notable reduction in costs partly through the very fact of the effect of

large-scale production on overhead, and partly through the technical improvements which large-scale production enabled mines and reduction works to install and make use of. High-cost mines might wither and die by the wayside if they must, under the double blight of high post-War labor and material costs and taxes, and low post-War copper prices; but the low-cost mines more than made up the difference. And this was going on outside the United States as well as here. The technical and economic facts being what they were, and the organization of the industry being what it was, large production was an inevitable consequence, almost regardless of price; indeed the declining prices have simply urged to greater technical efficiency and more output. Rapidly growing supplies of scrap or secondary copper did their part in keeping down prices.

A volume could be written in this price field alone. This must suffice, both as a summary of major copper-price movements and as a conclusion to this chapter. The chapter has endeavored to trace some of the outstanding features of an industry which reaches at least back to the bronze age of prehistoric times. The industry had made almost no progress in the course of millenia of history, but in the last fifty years has been completely revolutionized, and through the accomplishments of the electrical industry has done much to revolutionize other industries throughout the civilized world.

CHAPTER VII

THE COTTON INDUSTRY

By C. T. Revere[1]

Importance of the Industry. Some conception of the importance and magnitude of the cotton industry of the United States may be gained from a comparison with other of our basic activities. The latest relative figures are those of 1923, and in this year the cotton industry stood third in number of wage earners, fifth in cost of raw material, sixth in the value of product, and seventh in value added by manufacture. In value of product, it was surpassed only by automobiles, iron and steel, meat packing, foundry and machine shop output, and printing and publishing.

The relative proportions change in exceptional years, and it is not unlikely that when the final figures are compiled on the operations for the record crop grown in the calendar year, 1926, and marketed in the cotton season of 1926–27, cotton will advance farther toward the head of the column. Moreover, it is not certain that in number of wage earners employed, full credit has been given to the detailed agricultural operation, with its millions of farmers, plow-hands, cotton pickers, and the host of employees engaged around cotton gins, cotton compresses, and the great and small warehouses of the country.

It is not only in its magnitude that cotton assumes an impressive status. It is interesting and important to note, of course, that it leads the nation's exports, with a total value frequently exceeding a billion dollars, while the wholesale cost of the manufactured products turned out by domestic cotton mills approximates two billion dollars.

Of perhaps greater importance is the essential relation it bears to other great industries. Probably no important national activity can be conducted without the assistance of cotton, the Proteus of

[1] Member of Munds and Winslow, New York.

agricultural products. A study of the varied uses of cotton reveals some interesting examples of Man's ability to find servants among the products of the earth. Every great industry is more or less dependent upon cotton. Railroads annually use the equivalent of several hundred thousand bales for air-brake hose, plush for car seats, for enameled ceilings that have a basis of cotton duck or other fabric. The cement industry transports its product today in cotton bags which took the place of barrels more than a quarter of a century ago when the low price of cotton attracted attention to its availability for this purpose. No one knows how many thousands of bales of cotton are employed in the construction of the modern skyscraper and well-built residence. Those who are observant will note that the asbestos cement covering around steam and hot-water pipes is held in place by light cotton duck.

The electrical industry today uses tens of thousands of bales of cotton for the insulation of copper wire. The automobile has become an important consumer of cotton. Tire fabric calls for hundreds of thousands of bales either of long-staple cotton for certain classes of fabric, or shorter staple which can be used in cord tires. Artificial leather, with cotton as a base, has become a competitor of hides in the upholstering trades, for automobile tops and curtains, and numerous other uses. The list might be extended into a veritable catalogue, but probably the most unique use to which this fiber is put is in the manufacture of "synthetic ivory," for billiard and pool balls, imitation tortoise shell toilet articles, and similar products.

The use of cotton "linters," the short fiber obtained from cotton seed after passing through the gins, in the manufacture of rayon, or artificial silk, forms the basis of another great and growing industry.

Modern farm implements require vast amounts of cotton. Self-binding reapers and threshing machines call for quantities of heavy cotton goods for elevators and belts. It might almost be said that the great grain crops of the world today could not be harvested and marketed without the use of cotton.

Although the spinning and weaving of cotton goes far back into the obscure mists of antiquity, its larger uses did not develop until the world entered upon the industrial awakening that had its beginning in England the latter part of the eighteenth century. In fact, it might be said that the cotton industry is more nearly

typical and representative of industrial growth than any other of our basic activities.

The manner in which the production of the raw material and the manufacture of the finished product kept pace with one another as inventive genius came into play constitutes one of the most interesting and romantic phases of human progress. There was a time in England when attempts were made to bar both the manufacturing and wearing of cotton goods on account of their competition with woolen and linen fabrics. The importation of muslins from India was strictly forbidden by statute. The urgent requirement for more wearing apparel and the craving for fashion and style changes carried the day, however, and cotton goods began to be manufactured in England in a small way. The raw material was obtained from India and the Near East, with Smyrna prominent among the exporting markets of the Levant.

Anglo-Saxon ingenuity set to work to solve manufacturing problems as more raw material became available. In the honor roll of these pioneers we find the names of Hargreaves, Arkwright, Watt, Crompton, and Cartwright, as well as Kay and Paul. From these sources came the first real labor-saving appliances that multiplied hand labor. The innovations were savagely fought by hand-spinners and hand-weavers, who saw poverty and starvation facing them while machines robbed them of the opportunity of earning their livelihood. The first machines were destroyed by mobs, and after they were replaced by improved devices, the inventors were deprived of the fruits of their effort by unscrupulous competitors.

Gradually, however, textile processes were improved by the fly shuttle, the spinning jenny, mule spinning invented by Crompton, the use of steam power, the development of the power loom, and other innovations.

Rise of the Industry in the United States. Finally the industry reached a stage where more raw material was needed. This came from an unexpected source — America. In 1784, eight bags of cotton imported from the United States were seized on the ground that the origin of the fiber had not been correctly declared — that such a quantity of raw material could not be produced in that country. In 1793, however, Eli Whitney invented the saw gin, and cotton growing in the United States started on its enlarged career.

The table herewith gives a graphic picture of the early beginnings of the cotton industry, the development of inventive genius as applied to textiles, and the growing use of cotton. The first column gives the importations of cotton into the United Kingdom for stated years and is figured in pounds instead of bales. It will be noted that in 1784, 1200 pounds of cotton were shipped from

TABLE I

	Cotton Imported into United Kingdom (In Pounds)				Inventions, Etc.
	All kinds	American	E. Indian		
1741	1,645,031	None	None	1738	Kay's "Fly-shuttle."
					Paul's spinning by "Rollers."
1751	2,976,610	None	None	1748	Paul's improved carding machine.
1764	3,870,392	None	None	1760	Kay's "Drop-box." 1764 Hargreaves's "Spinning Jenny."
1769	No record		None	1764	Calico printing introduced into Lancashire.
1770	No record		None	1769	Arkwright's first patent. Watt's first patent.
1771				1770	Hargreaves's first patent.
to	4,764,589	None	None	1771	Arkwright's mill built at Crompton
1775				1773	Arkwright's and Wood's carding machines.
1776				1775	Arkwright's second patent.
to	6,766,613	None	None	1779	Crompton invents mule.
1780					
1781	5,198,778	None	None	1781	Watt's second patent. Muslins first made. First import of Brazil cotton — very dirty.
1782	11,828,039	None	None	1781	Watt's further improvements.
					Export of cotton machinery prohibited: penalty £500.
1783	9,735,663	None	114,133	1783	Cylinder printing invented by Bell.
1784	11,482,083	1,200	11,440	1784	Quantity of cotton imported from United States seized on ground that it was not American produce. German fined £500 for enticing cotton operatives to Germany.
1785	18,400,384	None	90,455	1785	Arkwright's patents thrown open. Steam engine first applied to cotton factory. Cartwright invents power-loom. Oxymuriatic acid first applied to bleaching cotton goods.
1786	19,475,020	None	None	1786	Arkwright knighted.
1787	23,250,268	None	None	1787	Cartwright's improved power-loom.
1788	20,467,436	None	None	1788	East India Co. pressed to push growth of cotton in India.
1789	32,576,023	None	4,973		
1790	31,447,605	None	422,207	1790	Arkwright adopts steam in his factory.
1791	28,706,675	189,316	3,351	1791	
1792	34,907,497	138,328	None	1792	Improvement made in mule by Kelley.
1793	19,040,929	487,600	729,734	1793	Whitney invents saw-gin. Improvement in mule by Kennedy.
1794	24,358,569	1,601,700	239,245	1794	
1795	26,401,340	6,276,300	197,412	1795	Improved saw-gin by Whitney.
1796	22,126,357	6,106,729	609,850	1796	Improvement in loom by Miller.
1797	23,354,371	3,788,429	912,844	1797	Scutching machine invented.
1798	31,880,641	9,360,005	1,752,784	1798	Tennant's patent for bleaching.
1799	43,379,278	9,532,263	6,712,622	1799	
1800	60,345,600	17,789,803	6,629,822	1800	

the United States. There is no record of any further shipments until 1791, when the amount is given as 189,000 pounds. In 1793, the year of Whitney's invention, the shipments reached 487,000 pounds. In seven years — by 1800 — this commerce had risen to more than 17,000,000 pounds. The last two columns of the table referred to give the years in which the epoch-making inventions of the cotton industry made their appearance.

Although American inventions have played their part in the textile industry, it is the opinion of students that the supreme contributions to the textile industry have come from England. The outstanding performance of America has been along the lines of producing the raw material and in preparing it for the market. The invention of the saw gin by Eli Whitney was, of course, the greatest achievement.

The saw gin is used entirely for separating short cotton from the seed. Another method is employed in the treatment of Egyptian and other long-staple cottons. This consists of the use of rollers which hold the fiber until the operation pulls it away from the seed. This method is employed because it has been found in practice that in the treatment of long-staple cotton the saws get tangled up with the fiber and cut it so that it is of uneven length.

Although proportions of production have shown considerable variation from year to year, the United States in periods of normal production has furnished approximately two thirds of the world's supply of cotton. Before the World War, our contribution ranged from about 65 to a little more than 67 per cent of the world yield. As a result of the disastrous ravages of the boll weevil in 1921, the production in this country dropped to about 7,900,000 bales, whereas the world crop amounted to 15,334,000. By 1924, our production had recovered to 13,628,000 out of a total of 23,825,000 bales. In 1925, we produced 16,104,000 out of a total of 26,618,000 bales. The world's crop for the calendar year 1926 was estimated roughly at a little less than 29,000,000 bales, although in this calculation the Department of Agriculture placed the yield of the United States at a probability of 18,618,000 bales of 500 pounds gross weight, exclusive of linters — the short fiber obtained by the cotton-seed oil mills from the treatment of seed. The linters from the crop of 1926 probably will exceed 1,000,000 bales. The final census giving report of 17,910,000 in 500-pound bales reduces the total by 700,000 bales.

The growing of cotton constitutes one of the leading agricultural operations of the United States. It probably presents more complexities than are involved in the case of any other of our great crops. Wheat and corn growing are simple operations compared with raising a cotton crop, where constant care is demanded over practically three fourths of the year.

FIG. 1. — Cotton plant.

In the United States, cotton is an annual plant. It is only in tropical or semi-tropical countries that it is a perennial. The labor of preparation, at least in districts infested by the boll weevil, must be started in the late autumn after the previous crop has been gathered. The old cotton stalks should be destroyed in order to remove places of refuge for hibernating weevils.

Actual soil preparation begins along in the winter with the early plowing, and in extreme south Texas this operation is well underway in January. This work proceeds in other parts of the cotton belt and continues throughout February, March, and April, according to latitude. It is considered advisable to permit the land to lie idle after the early plowing in order that the soil may receive the benefit of the spring rains.

Winter moisture is nearly always a decisive factor in the making of the cotton crop. This is particularly the case in Texas and Oklahoma, where spring and summer rainfall usually is much lighter than it is in the Mississippi Valley and the states eastward. In cotton parlance, this is known as the " season in the ground," and if precipitation is heavy in November, December, January, and February throughout Texas and Oklahoma, the well-informed

student of cotton begins to figure on favorable chances for full production.

Cotton is known as a "dry-weather plant," and it is interesting to note the remarkable production resulting in the face of deficient summer rainfall, even with high temperatures, if the soil has been favored by heavy winter rains, thus permitting the storing up of a reservoir of subsoil moisture. The plant under these conditions develops a long tap root that strikes deep into the soil in its quest for moisture. It is nothing unusual to see a cotton plant not over a foot and a half high with a tap root a foot or more in length. This is a natural phenomenon in a season marked by early heavy winter rains, followed by dry weather.

The reverse of this situation is presented by a wet spring when the ground is water-soaked and cultivation thereby is made difficult. Instead of a long tap root boring its way into the soil, the plant develops an abundance of lateral roots that spread out in all directions just a little under the surface of the ground. The plant becomes green and "sappy," and in no condition to withstand the rigors imposed by a sudden change or by prolonged dry, hot weather. Under these conditions, the plant wilts rapidly and if the fruiting season has commenced, it sheds its squares and blooms, and frequently the young, partially developed bolls.

After the soil has been prepared by the usual plowing and, in the case of progressive farmers pulverized by harrowing, the planting operations begin. The earliest planting, of course, is undertaken in extreme southwest Texas along in early February, and in exceptional seasons even in January, although this is rare and over limited areas. General planting in the southern half of the belt usually begins in March and in ordinary years is completed in May in the northern latitudes. Instances are not infrequent, however, of cotton planted in June where the work has been delayed by floods or overflows along the Mississippi with ultimately satisfactory results.

A dry May and a moderately dry June provide favorable conditions for the development of the plant, dependent of course upon the amount of subsoil moisture. In the so-called weevil areas, the minimum of moisture required for sustaining the plant and furnishing enough nourishment for fruiting will give the best ultimate results. July also should be a moderately dry month. By this time the crop, of course, has been "laid by," cultivation

having been completed, unless drought or insect conditions necessitate its continuance. One or two good soaking rains in August will provide enough moisture to carry the crop through the fruiting period and prevent excessive shedding. After this all that is required is a favorable picking season and an abundance of labor for the gathering of the crop.

Cotton is a plant with many insect enemies. Among the minor pests is the cotton louse that makes its appearance in the cool weather of the spring and saps the vitality of the young plant by sucking the buds. In the season of 1926–27, a scare was created by the appearance of the cotton flea or "hopper." This also is a sucking parasite that attacks the young buds and causes extensive shedding, thus delaying the progress of fruiting. Both the louse and the cotton flea, however, disappear later in the season, and their ravages are not important.

Among other minor pests might be noted the grasshoppers, which in certain portions of the southwest destroy the foliage over a wide area and cause considerable consternation. The army worm and the so-called leaf worm frequently appear in vast numbers and defoliate thousands of acres and sometimes create the impression of complete devastation. There are seasons, however, when their visit is not unwelcome, as the plants frequently attain luxuriant proportions and the excessive foliage prevents the ripening of the bolls. The work of pruning by these insects consequently permits the bolls to mature and open more rapidly than would be the case otherwise.

The arch enemy of the cotton grower is, of course, the boll weevil, which made its invasion of the cotton belt from Mexico. In certain seasons this pest has been credited with destroying several million bales in a single year. The insects multiply rapidly and in certain weeks of migration along in August and early September spread over a large territory. The female punctures the bud or "square" of the cotton plant and after depositing an egg seals up the aperture with a waxy substance. The egg hatches in about three days, and in from seven to twelve days the larva or grub reaches the pupa stage, and in from three to five days the adult weevil makes its appearance. The female weevil is credited with laying about five eggs per day for a period of about thirty days. Consequently, the pest multiplies with amazing rapidity.

Various methods of scientific control have been tried. The

first essential is reducing the facilities of the weevil for winter hibernation. When the pest makes its appearance in the fields, the progressive farmer makes every effort to gather the "squares" that have fallen between the rows from the plants. These "squares" contain the larvæ of the weevil and drop off the plant after insect development has reached such a stage that the bud becomes diseased.

The government entomologists have experimented with a number of poisons; the most efficacious thus far is calcium arsenate, which either is dusted on the plant or spread in the form of a liquid mixture with molasses to cause adhesion. In rainy seasons the work of poisoning is rendered extremely difficult because the showers wash the poison from the plant.

Fig. 2.—Boll weevil—greatly magnified.

Climatic conditions probably afford the best control of the weevil. This insect possesses extraordinary vitality and has been known to stand temperatures well below freezing. However, temperatures of ten degrees and below reduce winter survival of weevils to a minimum degree. In fact, areas visited by such weather in the winter would be practically immune were it not for the migration of weevils from the lower latitudes as the summer progresses.

Hot, dry weather also acts as a serious check on weevil propagation. When the "squares" containing the larvæ fall to the ground, they are literally cooked by the broiling sun during the hot weather and so removed as a source of further trouble. On the other hand, if the weather is cloudy and showery or the plant as a result of rainy weather becomes luxuriant enough to afford shade for the grubs as they drop to the ground, the embryonic insects survive and become instruments for further destruction.

The winter of 1920–21, as well as the season following, was extremely mild and weevils emerged in vast numbers, causing widespread destruction. On the other hand, the cold winters of 1924–25 and 1925–26 furnished temperatures low enough to reduce

spring emergence materially and give the cotton growers a chance to pursue their cultivation with minimum interference.

Another dangerous pest is the cotton-boll worm which has appeared in portions of Texas and Oklahoma. It is most destructive in rainy periods in the late summer and autumn. The poisoning methods which check the boll weevil are also effective against the boll worm.

It seems pertinent at this time to make brief reference to the cost of producing cotton. This is a question that cannot be answered categorically as everything depends upon the yield per acre and the amount of time and labor that must be spent in giving effective cultivation and fighting insect pests. Some extravagant claims have been made regarding the cost of growing cotton, and in 1923 when the price crossed thirty-five cents per pound it was contended that the staple could not be grown at a profit for less than twenty-five or thirty cents.

It is true that in districts where weevil ravages reduce the yield to a bale to ten acres and farmers have fought vigorously against weeds and have spent considerable sums in the effort to combat the weevil, the cost may rise to an extraordinary degree. In seasons of full production, costs drop materially. For the season of 1926–27, however, the Department of Agriculture estimated the average yield per acre at 180.2 pounds or more than a third of a bale to the acre. The average cost probably would be figured around fifteen to sixteen cents per pound with a production of this size. In 1925 the average production was placed at 167.2 pounds per acre, and in the five-year period from 1921 to 1925, the average was placed at 144.2 pounds.

In any season some producers will raise cotton at a profit, while some will have a loss in the operation. Intensive cultivation provides the best results. Some interesting figures are revealed in the report of the American Cotton Association for 1926 in the results on several hundred two-acre cotton demonstration farms which were intensively cultivated and distributed throughout North and South Carolina, Georgia, Alabama, and Mississippi.

The best examples were furnished by five growers, one in each of the above-named states. The average yield per acre was 913 pounds of lint cotton. The cotton and seed brought an average price of $140.64 per acre. The average cost of production per acre was $59.98. The average net profit per acre was $80.66.

The cotton was sold at an average of 13½ cents per pound, and the seed at $20 per ton. The average cost of production was placed at 6½ cents per pound.

The average yield of the several hundred two-acre cotton demonstration farms was 498 pounds of lint cotton per acre. The average cost of production was placed at $41.21 per acre, and the average net profit per acre was $32.28.

Production and Process. It is illuminating to study the record of one hundred years in cotton production with the high and low prices for spot cotton, New York quotations on middling, for each year. Table No. II herewith gives this record covering a century of production and prices. The figures are exclusive of "linters."

It will be noted that the production of cotton has increased sharply in the last four years. In 1923, the yield was only 10,170,000 bales. The next season showed an increase of 3,500,000 bales to the basis of 13,639,000. In 1925 the production was 16,103,000. In 1926 the production, according to the final report of the Census Bureau, was 17,755,070. This has come about partly as a result of improved weather conditions and less damage by weevil, but even more through the great increase in acreage. For the season of 1923–24, the acreage planted to cotton, revised figures, was 38,724,000. For the season of 1924–25, the revised report showed 42,641,000 acres; for the season of 1925–26, the area was placed at 46,053,000 acres. The Department of Agriculture estimated the acreage for the season of 1926–27 at 48,898,000 acres, but in its final report issued December 8, it placed the harvested area at 47,653,000 acres. The crop of 1914–15, which amounted to 16,134,000 bales, was produced on an acreage of 37,406,000 acres, revised figures.

The crop of 1897–98 furnished the greatest average yield per acre, 222 pounds per acre. In 1926–27, while the crop broke all previous records as to total size, the average yield per acre was only 180.2 pounds, based on final ginning returns.

In discussing the question of cotton production, it may be well at this point to consider world production with comparative figures on recent years for various countries. Without doubt, the high prices which prevailed for American cotton during the War and shortly afterward stimulated efforts to grow cotton in other countries. British interests have spent vast sums in attempting to increase the yield along the Nile and also in the Sudan. Cotton

TABLE II

Year	Crop Ex-Linters (in 500 Bales)	New York Mid. High	Spot Low	Year	Crop Ex-Linters	New York Mid. High	Spot Low
1826	957,281	11½	8¾	1882	6,949,756	12⅞	10
1827	720,593	13	8¼	1883	5,713,200	10	9
1828	870,415	11½	8	1884	5,706,165	10⅛	9⅞
1829	976,845	12½	8	1885	6,575,691	10	9⅛
1830	1,038,847	13¼	7½	1886	6,505,087	11⅜	9⅛
1831	987,477	12	7	1887	6,938,290	11	9½
1832	1,070,438	17	9½	1888	6,938,290	11½	9¾
1833	1,205,394	18	9½	1889	7,311,322	12⅝	10¼
1834	1,254,328	20	12½	1890	8,652,597	10⅝	8
1835	1,360,725	20	12½	1891	9,035,379	8¾	6¾
1836	1,423,930	20	7½	1892	6,700,365	10	7¼
1837	1,801,497	14	7¼	1893	7,549,817	8⅝	6⅞
1838	1,360,532	17	9½	1894	9,901,252	8¼	5⅜
1839	2,177,835	13½	6	1895	7,157,346	9	7⅛
1840	1,634,954	11½	7	1896	8,757,964	8⅞	7
1841	1,683,574	10½	5	1897	11,199,994	8	5¾
1842	2,378,875	8½	6⅛	1898	11,274,840	6⅝	5⅜
1843	2,030,409	9½	5¾	1899	9,436,416	10¼	6¼
1844	2,394,503	6¾	5	1900	10,102,601	11.00[2]	7.62[2]
1845	2,100,537	9½	7	1901	9,583,589	12.00	7.87
1846	1,788,651	13¾	8½	1902	10,588,684	9.87	8.25
1847	2,439,786	13	6	1903	9,820,397	13.70	8.85
1848	2,866,938	10⅝	5⅞	1904	13,451,386	16.65	6.85
1849	2,333,718	13⅞	10	1905	10,495,118	12.60	7.00
1850	2,454,442	15	8¾	1906	12,983,102	12.25	9.60
1851	3,126,310	11⅜	8½	1907	11,058,340	13.55	10.60
1852	3,416,214	11¾	9¾	1908	13,086,182	12.25	9.00
1853	3,074,979	11¾	10	1909	10,073,223	16.10	9.25
1854	2,982,634	13	8½	1910	11,568,174	19.75	13.60
1855	3,655,557	11⅝	9	1911	15,553,073	16.15	9.20
1856	3,093,737	15¾	11⅝	1912	13,488,539	13.40	9.25
1857	3,257,339	15¾	9⅞	1913	13,982,811	14.50	11.70
1858	4,018,914	13⅜	11	1914	16,134,930	14.50	7.25
1859	4,861,292	11¾	10½	1915	11,068,173	12.75	7.90
1860	3,849,469	22	10	1916	11,363,915	27.65	13.35
1861	4,500,000	51½	20	1917	11,248,242	36.00	21.20
1862	1,600,000	92	51	1918	11,906,480	38.20	25.00
1863	1,450,000	93	51	1919	11,325,532	40.50	27.00
1864	1,300,000	$1.90[1]	72	1920	13,270,970	43.75	13.16
1865	2,269,316	1.20	35	1921	7,977,778	22.38	10.85
1866	2,097,254	42	26½	1922	9,729,306	26.87	15.03
1867	2,519,554	32¾	15¼	1923	10,170,694	37.70	20.68
1868	2,366,467	35	24¼	1924	13,639,399	35.70	22.10
1869	3,122,551	35	19¼	1925	16,103,679	26.05	18.36
1870	4,352,317	21	14¾	1926	17,755,070[3]	21.25	11.55
1871	2,974,351	26¾	18⅜				
1872	3,930,508	21¼	18⅛				
1873	4,170,388	20⅝	13¼				
1874	3,832,991	17⅛	14½				
1875	4,632,313	14⅝	11¾				
1876	4,474,069	13¼	10⅞				
1877	4,773,865	12⅛	10⅝				
1878	5,074,155	13⅛	8¾				
1879	5,761,252	13¼	10½				
1880	6,605,750	13	10½				
1881	5,456,048	13	11½				

[1] Highest price on record. [2] Prices in hundredths of cent per pound.
[3] Census ginning running bales.

growing has been stimulated in Turkestan, Mesopotamia, Brazil, and Argentina.

Owing to soil fertility, favorable climatic conditions, and experience extending well over a century, the southern part of the United States probably can grow cotton more cheaply than any other country except in seasons where conditions lay the basis for heavy damage by the boll weevil.

Those who are interested in world production of cotton and who wish to note the competition that may have to be met by the United States through the efforts of other countries will find the accompanying detailed table on the world's cotton crops of more than usual value. The figures are the latest compiled by the United States Department of Agriculture and give the production by specified countries for years beginning with August 1 and ending July 31, the year following. The report covers the seasons of 1923–24 to 1925–26, on which complete returns have been received.

The preliminary figures in the final column, although representing official estimates, must not be accepted as the final production.

Attention is called to the increase in cotton production for Anglo-Egyptian Sudan, Uganda, Asiatic Turkey, and Asiatic Russia. It will be noted that the latter country has increased its production from about 196,000 bales for the season of 1923–24 to 736,000 bales for the season of 1925–26. Probably no better example of agricultural recovery in the Old World since the War may be found than is furnished by figures on Asiatic Russian cotton production. The yield has been reduced to the uniform quantity of 478 pounds net.

After the months spent in the production of a cotton crop involving endless labor for cultivation and fighting insect pests, it might be said that the work of the cotton belt is only half done. There still remain the complicated tasks of picking, ginning, and distribution, not only to the manufacturers of the United States but to export outlets as well. Aside from extreme southwest Texas where " first bales " are sometimes received early in June, picking does not become a general operation until the latter part of July and along in August. By the time the cotton harvest begins in North Carolina, north Alabama, and Tennessee, it has been practically finished in south Texas, south Georgia, and south Mississippi. In the average year, the crop is about sixty per cent gathered by the first of November. In late seasons, picking is not

TABLE III

WORLD'S PRODUCTION OF COTTON BY SPECIFIED COUNTRIES FOR YEARS BEGINNING AUGUST 1 AND FOR THE SEASONS 1923–24 TO 1925–26 COMPLETE AND PRELIMINARY FIGURES FOR 1926–27 FOR COUNTRIES REPORTING UP TO APRIL 1, 1927.

(In bales of 478 pounds net)

COUNTRY	1923–24	1924–25	1925–26	1926–27 PRELIMINARY
NORTH AMERICA				
United States [1]	10,140,000	13,628,000	16,104,000	18,618,000
Mexico	175,380	298,000	202,200	396,000
Total North American countries reporting 1923–24 to 1925–26	10,315,380	13,926,000	16,306,200	19,014,000
SOUTH AND CENTRAL AMERICA AND WEST INDIES				
Peru	202,983	205,985 [2]	200,000	
Ecuador	11,079	11,500 [2]	6,100 [2]	6,340
Brazil	576,000	605,000	601,500	
Paraguay	16,265	12,222	10,400	
Argentina	58,846	66,668	134,800	
Guatemala [1]	709	1,549	1,600	
Haiti	15,500	15,300	15,000	
Dominican Republic	448			
Porto Rico	1,020	1,900	1,900	
Salvador		11,500	11,000	
British West Indies	5,329	4,579	4,395	
Total South and Central American countries and West Indies reporting 1923–24 to 1925–26	857,105	897,006	955,617	

Division of Statistical and Historical Research. Official sources and International Institute of Agriculture except as otherwise stated. Data for crop year as given at the head of the table are for crops harvested between August 1 and July 31 of the following year. For the United States prior to 1914 the figures apply to the year beginning September 1.

[1] Linters not included. Production of linters during this period has been: Average 1909–10 to 1913–14, 502,711 bales; 1923–24, 668,600 bales; 1924–25, 897,375 bales; 1925–26, 1,114,877 bales.

[2] From an unofficial source.

TABLE III (*Continued*)

Country	1923–24	1924–25	1925–26	1926–27 Preliminary
Europe				
Italy	5,000	4,500		
Yugoslavia	203	385	600	
Greece	11,135	18,325	14,800 [1]	35,000
Bulgaria	1,795	2,959	1,700	3,000
Malta	100	480	655 [1]	424
Spain	314	1,266 [1]	1,218	3,000
Total European countries reporting 1923–24 to 1925–26	1,895	3,439	2,355	
Africa				
Algeria	793	2,230	5,800	11,000
Morocco (French)			800	900
French West Africa Dahomey	1,483 [1]	1,483		
Ivory Coast	1,211 [1]	1,212		
French Guinea	375	404	461	
Senegal	1,199	1,845	2,767	
French Sudan		4,843		
Upper Volta	4,612	10,972	11,069	
French Togo	4,598	7,615		
Nigeria	21,368	30,475	39,330	
French Equatorial Africa	1,172	1,408		
Egypt	1,353,000	1,507,000	1,629,000	1,497,000
Anglo Egyptian Sudan	38,221	40,665	110,000	120,000
Italian Somaliland	1,750	2,305	5,000	
Eritrea	1,384	2,780		
Gold Coast	837	1,250		
Belgian Congo	15,833	18,450		
Kanya	1,674	11,281		
Uganda	107,619	164,046	159,100	
Tanganyika	9,568	15,726	18,100	20,755
Nyasaland	3,777	5,538	6,459	
Northern Rhodesia	397	409		
Southern Rhodesia	1,179	4,010		
Mozambique	5,955	2,496	2,500	
Union of South Africa	7,000	14,172	26,200	
Total African countries reporting 1923–24 to 1925–26	1,532,335	1,764,201	1,975,089	

[1] From an unofficial source.

TABLE III (*Continued*)

Country	1923–24	1924–25	1925–26	1926–27 Preliminary
Asia				
Cyprus	1,680	2,556	2,600	
Turkey, Asiatic . . .	57 000	78,400	105,172 [1]	120,000
Syria	8,300	20,800	12,700	
Russia, Asiatic . . .	196,400	483,500	736,600	755,500
Iraq	827	2,092	2,080 [1]	2,929
Persia				
India	4,320,000	5,095,000	5,053,000	4,144,000
China	1,993,000	2,179,000	2,114,000	1,584,000
Japanese Empire . .				
Japan	2,316			
Chosen (Korea) . .	110,046	121,088	125,000	153,815
French Indo-China . .	9,086 [2]	10,470 [2]	10,977	
Dutch East Indies . .	7,321			
Siam	3,062	4,336	4,062	
Total Asiatic countries reporting 1923–24 to 1925–26	4,640,274	5,716,950	5,932,239	
Oceania				
Australia	10,042	14,435	6,300	
New Hebrides . . .	1,828	2,134		
Total Oceania reporting 1923–24 to 1925–26 .	10,042	14,435	6,300	
Total all countries reporting 1923–24 to 1925–26	17,357,031	22,322,031	25,177,600	
Estimated world total including China . .	19,700,000	24,900,000	27,700,000	

completed in scattered areas until along in March. This was the case in the spring of 1921, as well as in the spring of 1927.

Cotton picking is a great industry in the south, particularly in years of large production. In late years, the price paid to pickers has ranged from $1.25 per hundred pounds of seed cotton in the early part of the season when cotton can be gathered rapidly, to $3 per hundred in the latter part of the season when such costs are so high that they do little more than pay for the recovery of the remnant of fiber in the field.

Cotton picking undoubtedly employs more people than any other

[1] From an unofficial source. [2] Annam and Cambodia only.

agricultural harvest of the country. In years when Texas produces a large crop, tens of thousands of Mexicans come over the borders and aid in the gathering of the crop.

Numerous attempts have been made to develop a mechanical cotton picker, but thus far these have not been successful, largely owing to the fact that, while it is possible to get the cotton off the plant and into the container, the fiber is much more trashy and filled with leaf than in the case of hand picking.

FIG. 3. — Weighing cotton gathered by pickers on a large plantation.

Cotton when picked is taken to the gins to remove the seed from the fiber. Generally speaking, it requires about 1500 pounds of seed cotton to produce a bale of approximately 500 pounds. In other words, a load of 1500 pounds of seed cotton furnishes about half a ton of seed and 500 pounds of lint cotton.

There have been numerous refinements since the day when Eli Whitney installed his first saw gin, but the principle in the operation has undergone no basic change. The saw gin has a cylinder about four feet in length and about six inches in diameter on which is a set of circular saws projecting about the revolving cylinder in series. The seed cotton comes in contact with the saws while the cylinder is revolving, but the latter is separated from the cotton by a grating. The teeth of the saws catch the cotton as it is forced against the grating, which will not permit the seeds to come

through. Underneath the saws are stiff brushes revolving in the opposite direction on another cylinder which remove the cotton from the teeth of the saws, where it is then conveyed by pneumatic suction to the gin box. The cost of ginning generally ranges between \$3.50 and \$5.00 per bale, including the cost of the jute bagging and the steel bands or ties.

The seed obtained by the grower constitutes no small part of his income. A farmer who raises ten bales of cotton will have five tons of seed which will command a price ranging from \$18 to \$30 per ton. The cotton-seed oil industry represents one of the important activities of the south with millions of capital invested, and annual products, including linters, cotton oil, cotton-seed cake and meal have a total value running into several hundreds of millions of dollars. In 1926, the value of 7,150,000 tons of cotton seed was placed at \$256,000,000. The high-water mark was reached in 1919 when 5,360,000 tons were given an estimated value of \$383,000,000.

When the cotton seed is received at the oil mills, the product goes through a process to remove the short fuzz remaining after the seed has come from the gin. These minute fibers in the case of careful ginning do not have a length of more than one eighth to three eighths of an inch. The commercial name of the product is "linters," and this goes into a variety of uses, including the stuffing of mattresses, making of absorbent cotton, for munitions, and in the last few years in the manufacture of artificial silk. In this latter process the linters are subjected to chemical treatment, made into a jelly-like mass, and then forced under high pressure through minute openings at the end of a closed chamber, where an entirely new synthetic fiber makes its appearance to be available for spinning and weaving. Both linters and wood pulp are employed in the making of rayon or artificial silk.

Marketing. The marketing of cotton is one of the chief commercial enterprises of the south. The grower, if a tenant, divides with his landlord. Other farmers may have pledged their crops to country merchants for supplies. At any rate, in the case of the small grower, the cotton is sold either to the country merchant or to town buyers who may be operating either for their own account or for large shippers. Sometimes the cotton may be sold directly to mill buyers, particularly if it is brought into a market where a mill is situated.

After the cotton passes out of the hands of the original growers, it moves to concentrating markets where it is assembled, inspected, and graded for distribution on a wholesale scale. These larger concentrating points usually have a compress where the cotton is placed under pressure and reduced in size. When the bale originally comes from the gin, it is an irregular rectangular package 27 × 54 × 56 inches, covered with mesh jute bagging and held together by six steel bands. It has identification marks which would permit the cotton even after it arrived in Europe to be traced back from the various hands through which it has passed to the original grower.

At the compress the bale is subjected to steam or hydraulic pressure, and the bale becomes of approximately the following proportions: 28 × 58 × 18. The density of pressure ranges from 25 to 29 pounds to the hundred weight, although railroad and steamship lines make a minimum requirement of 22½ pounds to the hundred weight. The so-called high density presses compress to 34 pounds to the hundred weight, thus making it possible to load more bales in a steamship for export.

The weighing, grading, and stapling of cotton are special operations necessary to meet trade requirements. The weight must be ascertained when the cotton is sold. The product must be equal to the specified grade or the spinner to whom it is sold will make claims upon the merchant from whom he bought it. Cotton also must have a length of staple equal to that mentioned in the contract of sale.

As stated above, when cotton is made ready for final distribution, it is weighed and inspected for length of staple and grade. The stapling of cotton is the process used for determining the length and strength of the fiber. Cotton in the less fertile lands of the eastern part of the Cotton Belt generally varies in length from three quarters of an inch to one inch. Cotton grown in the prairie lands of Texas and Oklahoma has a length of about one inch to one and one sixteenth inches. Long-staple varieties are planted in the fertile districts of every state, and the best cotton, having a heavy bodied character, comes from the rich alluvial soil of creek and river bottoms in portions of South Carolina, southern Alabama, the delta district of Mississippi, and the river bottoms of Arkansas, Oklahoma, and Texas.

Cotton of this character ranges in length from one and one

sixteenth inches to one and five sixteenths. It commands a stiff premium, not only on account of its length but also because of its so-called heavy body. Staple cotton is used for making the finer grades of cotton cloth such as sheer muslins, voiles, etc. In considering long-staple cotton, one should not overlook the "Pima," or what has been termed American-Egyptian cotton, grown in the irrigated districts of Arizona and California. A number of years ago the Sea Island cotton grown along the coast and on the islands off the coast of South Carolina and Georgia was considered the finest commercial cotton grown. It frequently had a length over two inches for the longest variety, and even surpassed the best Egyptian cotton. Sea Island production, which along in 1910 and 1911 approximated 120,000 bales, has dropped to practically nothing. In fact, the Census Bureau in its report on the crop of 1925–26 makes no mention of the production of Sea Island cotton. Its cultivation was abandoned because of the damage inflicted by the boll weevil. Long seasons were required to produce Sea Island cotton and the weevil consequently was more destructive than in the case of varieties that develop more quickly.

More uniform methods for determining the grade of cotton are now followed than was the case a number of years ago when practically every market had its own types under special names. The passage of the United States Cotton Futures Act required all markets in this country to adopt the so-called "Government Standards," which specified the following grades: Middling Fair; Strict Good Middling; Good Middling; Strict Middling; Middling; Strict Low Middling; Low Middling; Strict Good Ordinary; Good Ordinary. These are the grades specified for white cotton, which, in the language of the Department of Agriculture, requires "that cotton grading Strict Good Middling or above, be of the bright creamy or white color and free from any discoloration." In addition to the white cottons, the Government Standards provide for "Tinges" and "Stains." In this category are Good Middling Yellow Tinged, Strict Middling Yellow Tinged, Middling Yellow Tinged, Strict Low Middling Yellow Tinged, Low Middling Yellow Tinged, Good Middling Yellow Stained, Strict Middling Yellow Stained, Middling Yellow Stained, Good Middling Blue Stained, Strict Middling Blue Stained, and Middling Blue Stained.

It requires much expert knowledge and experience to class cotton properly, both in respect to determining the length of staple and

the grade. Samples ranging from a pound and a half to two pounds of cotton are taken from a bale, and in the case of compressed bales after they have been left in the sample room for twenty-four hours exposed to the air, they are carefully examined under a north light. The grade of cotton cannot be satisfactorily determined on dark, cloudy days or under artificial light. Some idea of the difficulties attending this operation are set forth in that notable work "Cotton and the Cotton Market," by W. Hustace Hubbard, in which the author, one of the keenest students the cotton trade has ever known, says:

"Cotton classing is an art and not an exact science. That simple sentence should always be remembered, for you will come across a lot of nonsense first and last about the classing of cotton exactly by standard. No two bales of cotton, no two cotton samples, are exactly alike in every particular, and, therefore, absolute matching of standards is impossible. You can approximate the standard, and you must do so in value, but no one can absolutely match two bales of cotton. The cotton classer, if one of the best, is born, not raised, for he has the artist's eye. You can teach the difference between good middling and strict middling, between white and tinged, but you cannot teach a man to be a 'good judge of cotton.' Such a man has the ability to place a bale of cotton instantaneously in its place without reference to either standard or type. He can place the doubtful bales, the samples on the line, in the proper grade at once, and when the shipment is all laid out, any one will pass those samples without question. It might be thought that good classers are rare, but they are more common than one would suppose. What is rare, is the ability to class cotton, coupled with the ability to merchandize cotton. When the two are combined, then you have one of the men who will make his mark in the trade."

Before cotton has been accepted by the ultimate buyer, it must come up to specifications as to weight, staple, and grade. Mill rejections may come from a variety of causes — loss in weight, water pack, mixed pack, sand and dust packs, gin cut — a defect usually caused by ginning the cotton when it is wet — and for a variety of other causes that produce an inferior article.

Lack of space prevents going into details concerning the various methods pursued in marketing the crop. Tenant farmers have to share with their landlords. Independent growers settle with the

country merchant either by turning in their cotton at a specified price or selling it and paying their season's bills. All operations are of a retail character until the cotton has passed through the hands of the country buyer or street buyer and finds its way to the larger markets where the operation takes on a wholesale character. Supply merchants and cotton factors also play their part. The cotton factor in former days was a more important individual than he is at present. His function was to advance money on the crop and finance operations for a rather large list of customers, among whom were many farmers who conducted operations on a large scale. He acted as banker in the early part of the season and became a selling agent when the crop moved to market. He received the cotton in his own warehouses and frequently was given discretion to sell whenever he considered the price satisfactory. In late years the country merchants and the country bankers have taken away much of the business that formerly went to the factor. The growing independence of the southern producer also has been an element in reducing the importance of this combination of middle man and banker.

Wholesale marketing of cotton is now handled cheaply by shippers who deal with domestic mills exclusively or for export as well and those who confine their operations entirely to exporting. In addition to these larger merchant firms are the coöperative marketing associations that have developed in a large way in the last ten years and who now have under their marketing control approximately 2,000,000 bales of cotton annually. Mr. Hubbard summarizes the progress of raw cotton to mill and back again in the form of the finished product as follows:

1. The farmer raises his cotton.
2. He takes it to town and sells it to a small dealer.
3. The cotton is resold by this small dealer to a larger firm located at the large interior markets or at the ports.
4. The cotton then passes either direct from these wholesalers to the mill in Europe or at home, or goes to another wholesaler at the mill centers. There used to be an intermediate stage here, when the cotton stopped at the port before being shipped out, but that has gone by.
5. (*a*) The cotton is bought by the mill as a rule through its own immediate broker.
   (*b*) The cotton is made up into goods.
   (*c*) The mill sells the goods either direct or through a cloth broker.

6. The goods pass into the hands of the large wholesale jobbers. In the case of goods coming back from Europe the jobber may either import direct or through an import house.
7. The goods are resold to the interior jobbers. As is the case with raw cotton, this phase may be skipped.
8. The goods are bought by the retailer either direct or through the interior jobber.
9. The retailer sells the goods to the individual consumer.

Probably no more graphic picture of the process can be given than this.

The larger "spot firms" dealing in cotton have extended organizations. They have numerous buyers in their employ operating throughout certain districts, and receive daily reports of purchases during the marketing season. They control warehouses and compresses and maintain selling agencies in important manufacturing centers in this country, as well as in the leading markets of Europe. They sell either directly to mills or operate through brokers at such points as Greenville, South Carolina, Charlotte, North Carolina, Providence, Fall River, New Bedford, and Boston.

Cotton is a cash commodity. All purchases are paid for on the spot, and consequently big firms and shippers during the height of the marketing season require credit on a large scale. Financing is done either in the form of time or demand loans, partly with securities as collateral and partly by warehouse receipts for the cotton. In the case of the larger firms, the financing operations through the Federal Reserve System have been of great assistance in moving the crop without credit strain. Not only the local banks get their paper rediscounted through the Federal Reserve Bank, but some of the big merchants finance themselves with acceptances.

Exporting firms also have the troublesome problem of foreign exchange to deal with. The seller is given reimbursement through cable instructions for drawing on banks in the leading European centers. When the cotton is ready for shipment, the merchant instructs his broker in foreign exchange to sell exchange against a given amount of cotton. The broker reports details of the sale, the name of the purchaser of the bill, the New York bank upon which the domestic draft is to be drawn, the rate and the time within which the draft must be sent to New York. The merchant then draws a domestic draft on the New York bank, figuring the

value of cotton from dollars into sterling or other foreign currency, and attaches to his draft the " first " and " second " of the foreign exchange drawn upon the reimbursement given him when the sale was made, two original bills of lading, two insurance policies, and if necessary, " hypothecation papers " authorizing the sale of the cotton to protect the drafts.

In the larger operations attending the marketing of cotton merchants have found it necessary to protect themselves in the futures contract markets. In the small operations of the country buyers, this may not be necessary, as the cotton changes hands rapidly and it may have been handled on a commission basis for one of the larger firms. It may be readily seen, however, that in the case of a firm which deals in tens of thousands of bales of cotton with accumulations subject to frequent and extensive price changes, the risk of loss between the time of purchase and the time of sale is an item that cannot be ignored. During the growing season, contracts are made by cotton merchants with manufacturers for sales of raw material to be delivered later in the season. These transactions are seldom made at a flat price, as the merchant does not know what price he will have to pay for his cotton, and he therefore cannot assume such a risk. The sales usually are made with some delivery month in the contract market used as a basis. One thousand bales of middling cotton, for example, would be sold for delivery to some New England mill at a premium of 150 points, or one and one half cents per pound, on the New York December position. If the cotton is sold on " buyer's call," the spinner determines the price by giving instructions for the purchase of 1000 bales of December cotton, for example, at 14.50 cents. His cotton, therefore, costs him delivered 150 points more, or 14.50 plus 1.50, equivalent to sixteen cents. If the purchase had been made at twelve cents, the cotton would have cost the manufacturer 13.50 cents. If the market should prove to be a strong and advancing one, the purchase for price fixation might have been made at 22 cents and the cotton delivered would cost 23.50 cents.

The futures contract market plays a most important part in the cotton trade, not only for providing a price basis, but also in furnishing price insurance to merchant firms. A spot firm doing a large business frequently accumulates thousands of bales of cotton for which it has at the moment no immediate outlet. If

these holdings amount, let us say, to 50,000 bales and the market should decline two cents per pound, or $10 per bale, the firm would be stared in the face by a loss of $500,000. It is just such risks as these that the establishment of the modern cotton exchanges was designed to prevent. Most firms when they buy cotton in the autumn during the height of the marketing season make it a practice to avoid being " long " to any appreciable extent. When the reports come in from the buyers of the merchant organizations giving the amount of the day's purchases, sales of contracts are made in the futures market, the New York Cotton Exchange, the New Orleans Cotton Exchange, and frequently by export firms on the Liverpool Cotton Exchange.

Consequently a firm that in the course of a week has bought 10,000 bales of actual cotton in excess of its sales to spinners, will sell 10,000 bales of December, January, or March contracts as protection. If the cotton has been bought " right " — that is, not out of line with contract prices — the operation as a rule should prove to be a satisfactory one. If the market declines, say two cents, and the actual cotton is sold to spinners on that basis, the short sales or hedges can be covered on a decline of approximately the same extent and thus the profit on the short sale will offset the loss in actual cotton.

In practice the proposition works out even more profitably, for if the actual cotton that has been bought is of a grade and character that is becoming relatively scarce as the season advances it increases in comparative value, even though contracts which represent merely cotton tenderable on the exchanges may be showing considerable weakness. The actual cotton, for example, may average middling inch cotton and may recede in price not more than 125 points, while the contracts sold at the time of the purchase may decline fully two cents. In this case the merchant not only protects himself fully, but makes a profit on the transaction.

In these days of wholesale commodity dealings, it would be impossible to transact a business without the insurance afforded by the cotton exchanges. The benefits accrue to all classes of the community. The merchant is insured against risks that he otherwise would not dare to assume. The spinner gets his raw material on a more reasonable basis. The ultimate buyer of goods reaps the advantage in the reduced price for the finished product.

It is within the limit of conservative claim to state that no com-

modity is handled on a smaller margin than cotton. This is because of the protection against loss afforded by the facilities for hedging against losses in price changes. Many firms consider themselves fortunate to obtain a profit of $2 per bale on the amount of cotton handled by them during a season. When one considers that prices for cotton have been as high as 35 cents per pound and in the last few years have averaged more than 20 cents per pound, some conception may be obtained of the narrow margin on which this business is done. Cotton at 20 cents per pound is equivalent to $100 per bale, and a profit of $2 means 2 per cent. It would be difficult to find any department of merchandising in which the basis of return is so small.

The explanation is simple. The department store or the retail merchant takes larger risks and consequently demands bigger profits. Thanks to the protection afforded by dealings on the cotton exchanges, thus minimizing the risk, the cotton merchant is prepared to do business on a smaller margin of profit. Losses, of course, are incurred, but they are borne by speculators who take larger risks in return for the chance to make larger profits. This, however, is a phase with which the cotton merchant, endeavoring to insure himself against loss, is not vitally concerned.

Probably no division of our agricultural and commercial activity is more important than the exportation of American cotton to the markets of the world. Our exports of cotton have a value in excess of any other commodity, whether raw material or manufactured articles. Time and again, it has kept the balance of trade in favor of this country. Our cotton goes to every industrial nation, and our exports of lint cotton and linters at times have exceeded a value of $1,000,000,000. The details of this commerce are fully set forth in the extended table on pages 282 and 283. The figures are those of the United States Department of Commerce and cover a range from 1893 to 1926 inclusive, giving the total value of cotton exports in each year and the names and takings of the principal importing countries.

Although the United States is the most important producer of cotton, there are certain varieties grown in other countries that it requires. Its annual imports of other growths lay the basis for a substantial commerce with certain countries. We require cotton from Egypt because of its long staple and silky fiber. With the passing of the Sea Island crop, we require a good deal of cotton

TABLE IV

Exports of Domestic Cotton and Linters — Value and Quantity, with Distribution of Quantity, by Countries to which Exported: 1893 to 1926

[Compiled from Commerce and Navigation of the United States. The figures in this table are for fiscal years]

Year	Total Value	Exports of Domestic Cotton (Equivalent 500-Pound Rates) to—						
		Total	United Kingdom	Germany	France	Italy	Spain	Belgium
1926	$917,719,940	8,211,647	2,297,641	1,690,307	943,586	745,070	314,619	203,461
1925	1,060,980,197	8,439,071	2,623,425	1,891,992	951,473	756,156	289,586	223,741
1924	903,975,146	5,898,713	1,694,895	1,345,554	751,424	563,733	216,253	168,968
1923	658,982,855	5,253,464	1,403,008	945,647	704,199	572,068	250,244	185,769
1922	596,378,864	6,717,757	1,806,743	1,616,674	820,049	468,590	341,551	186,272
1921	600,185,629	5,622,777	1,786,984	1,152,424	590,630	558,015	260,990	166,018
1920	1,381,707,502	7,087,487	3,444,794	420,758	596,391	617,263	275,034	209,572
1919	873,579,669	5,525,893	2,494,009		773,744	557,549	281,343	72,652
1918	655,024,655	4,641,023	2,387,101		658,553	369,213	259,194	
1917	543,074,690	6,176,162	2,895,423		1,055,749	687,158	394,093	
1916	374,186,247	6,168,140	2,760,890		890,376	836,915	340,246	
1915	376,217,972	8,807,157	3,919,749	294,194	692,699	1,127,400	464,504	5,057
1914	610,475,301	9,521,881	3,581,501	2,884,324	1,139,399	537,357	297,339	227,474
1913	547,357,195	9,124,591	3,716,898	2,443,886	1,074,987	500,823	317,954	226,967
1912	565,849,271	11,070,251	4,343,108	3,156,171	1,228,294	636,077	313,500	211,903
1911	585,318,869	8,067,882	3,461,054	2,202,707	1,021,998	436,296	242,073	150,225
1910	450,447,243	6,413,416	2,444,558	1,887,657	968,422	393,327	178,455	102,346
1909	417,390,655	8,895,970	3,665,355	2,438,090	1,098,173	565,695	301,789	157,631
1908	437,788,202	7,633,997	2,956,352	2,385,663	889,083	418,921	262,744	119,470
1907	481,277,797	9,036,434	3,966,119	2,315,651	1,006,633	567,916	275,868	154,168
1906	401,005,921	7,268,090	3,181,143	1,871,441	817,583	486,607	241,747	114,673
1905	379,965,014	8,609,698	3,967,254	2,011,679	818,304	534,735	295,537	145,564
1904	370,811,246	6,126,386	2,475,752	1,797,354	734,286	363,295	184,862	105,213
1903	316,180,429	7,086,086	2,799,096	1,915,094	806,673	444,950	266,336	157,351
1902	290,651,819	7,001,558	3,132,324	1,705,815	775,773	445,437	270,602	132,232
1901	313,673,443	6,661,781	3,106,857	1,629,935	754,329	365,359	237,346	154,682
1900	241,832,737	6,201,166	2,302,128	1,619,173	736,092	443,951	246,612	148,319
1899	209,564,774	7,546,821	3,609,444	1,728,975	803,406	417,353	248,635	129,524
1898	230,442,215	7,700,529	3,532,101	1,858,525	842,038	387,581	263,648	161,941
1897	230,890,971	6,207,510	3,127,186	1,371,577	716,025	323,117	219,088	83,485
1896	190,056,460	4,670,453	2,267,222	1,038,457	478,265	261,644	216,178	87,966
1895	204,900,990	7,034,866	3,553,782	1,504,631	790,699	332,656	255,679	145,340
1894	210,869,289	5,366,565	2,970,903	909,389	610,854	211,716	225,364	128,907
1893	188,771,445	4,424,230	2,363,176	850,387	568,059	160,019	200,212	90,399

from Egypt. The largest importations from that country were in 1920, when we took 485,000 bales. Strange as it may seem, we take a considerable quantity of cotton from China. This is a very short staple and of a rough curly variety. Most of it goes into cheap woolen manufactures. We take considerable cotton from Peru, usually what is known as Peruvian "rough," also employed in woolen manufacture. The cotton received from India and Mexico is chiefly short-staple varieties bought mainly on

TABLE IV — *Continued*

EXPORTS OF DOMESTIC COTTON AND LINTERS — VALUE AND QUANTITY, WITH DISTRIBUTION OF QUANTITY, BY COUNTRIES TO WHICH EXPORTED: 1893 TO 1926

[Compiled from Commerce and Navigation of the United States. The figures in this table are for fiscal years]

Year	Exports of Domestic Cotton (Equivalent 500-Pound Bales) to —							
	Russia [1]	Austria [2]	Netherlands	All Other Europe	Japan	Canada	Mexico	All Other Countries
1926 . .	235,775	618	125,891	155,250	1,118,261	253,932	568	126,668
1925 . .	286,367	571	151,285	157,430	849,584	206,853	81	50,527
1924 . .	120,318	2,144	112,456	153,233	583,957	151,731	1,082	32,965
1923 . .	7,274	2.958	75,618	167,646	679,158	217,052	15,492	27,331
1922 . .		4,008	96,203	135,614	895,367	201,166	6,195	139,325
1921 . .		5,862	98,754	155,056	554,892	169,166	70,602	53,384
1920 . .		42,858	186,476	183,729	876,250	216,606	1,141	16,615
1919 . .	310	55,386	57,949	203,949	809,313	203,015	1,707	14,967
1918 . .	15,945		10,098	82,572	583,546	249,973	10,706	14,122
1917 . .	49,189		62,161	184,717	530,892	187,201	5,298	124,281
1916 . .	173,449		102,087	169,154	503,077	197,659	23,695	170,592
1915 . .	82,125	455	544,035	898,096	428,806	182,790	39,727	127,520
1914 . .	99,076	106,511	35,053	63,725	353,440	150,993	34,671	11,018
1913 . .	74,907	113,182	14,537	55,376	396,779	152,015	20,977	15,303
1912 . .	112,262	125,564	35,242	83,821	480,934	181,667	16,129	145,579
1911 . .	84,941	79,530	18,124	48,713	156,724	156,824	4,631	4,042
1910 . .	67,203	57,220	18,823	43,378	95,000	125,592	29,604	1,831
1909 . .	96,675	94,782	30,129	58,174	208,943	131,453	42,575	6,506
1908 . .	98,371	90,049	27,684	62,125	200,396	113,997	4,997	4,375
1907 . .	121,141	113,630	29,092	65,083	262,283	150,343	732	7,775
1906 . .	112,480	56,375	18,490	44,486	147,269	141,908	29,285	4,603
1905 . .	129,060	62,572	31,163	72,911	336,575	115,857	79,082	9,405
1904 . .	168,506	28,158	16,055	61,488	45,870	88,795	56,172	580
1903 . .	181,938	39,912	42,542	82,243	152,826	127,640	66,507	2,978
1902 . .	73,446	39,757	22,418	61,679	178,505	129,016	27,500	7,054
1901 . .	53,171	37,238	53,180	52,325	78,558	102,980	35,103	718
1900 . .	54,950	44,919	74,635	65,635	323,202	109,983	18,522	13,045
1899 . .	95,012	57,127	51,621	84,500	182,734	98,230	36,130	4,130
1898 . .	103,825	35,614	43,509	69,189	224,214	122,495	42,433	13,416
1897 . .	84,570	23,971	34,731	48,790	64,022	80,408	30,207	333
1896 . .	91,622	15,912	14,219	51,367	40,388	68,074	38,817	322
1895 . .	141,998	24,852	25,999	55,319	22,130	105,534	75,953	294
1894 . .	140,082	960	18,581	39,686	9,603	65,085	35,165	270
1893 . .	36,356		26,614	22,449	1,586	62,988	41,812	173

[1] Includes Finland and Poland prior to 1919.
[2] Includes Czechoslovakia and Hungary prior to 1920.

account of their relative cheapness in price. The table at the top of the next page gives the details of imports from 1914 to 1926, inclusive, for the leading countries, expressed in equivalent 500 pound bales.

Consumption. World consumption of cotton has been increasing rather steadily for the last five years and is now at high-water

TABLE V

Total Imports into United States of Cotton, by Countries of Production, for Years Ending July 31, 1914, to July, 1926, Inclusive

Year	Total	Imports of Foreign Cotton (Equivalent 500-Pound Bales) Produced in —					
		Egypt	China	Peru	India	Mexico	All Other Countries
1926	325,511	238,620	22,452	16,637	22,143	23,553	2,106
1925	313,328	190,313	33,702	13,389	28,147	44,384	3,392
1924	292,288	164,152	45,118	19,928	34,419	27,062	1,609
1923	469,954	329,335	50,239	21,186	22,124	45,679	1,391
1922	363,465	233,729	15,563	38,753	10,348	53,637	11,435
1921	226,341	87,168	14,722	22,597	8,489	88,155	5,210
1920	700,214	485,004	57,185	63,426	14,343	65,343	14,898
1919	201,585	100,006	10,871	25,230	2,893	54,434	8,151
1918	221,216	114,580	38,964	19,692	7,096	35,726	5,158
1917	291,957	199,892	36,063	11,069	3,860	32,858	8,215
1916	437,574	350,796	35,792	10,909	4,214	30,098	5,765
1915	382,286	252,373	25,631	10,353	7,845	85,180	904
1914	260,988	38,579	20,772	12,627	7,849	80,285	876

mark. The record for all time was reached in the season of 1925–26, and it is clearly foreshadowed that there will be another large increase for the season of 1926–27. The gains have been made chiefly by the Continent of Europe, where the textile industry has been reviving, and by Japan. The United States has made some expansion, but, as will be shown later in discussing the position of this country in respect to domestic operations, the growth has been interfered with by the readjustments in the area of operations between Northern and Southern mills. Table VI gives the general details of world consumption of all kinds of cotton for the five seasons from 1921–22 to 1925–26, inclusive.

A study of the textile equipment, with particular relation to spindles, will give a clear idea of the methods by which cotton is consumed in various countries. World spindleage in 1926, as set forth in Table VII, stood at 164,210,000 spindles. It will be noted that the United States with a spindleage of 37,586,000 consumed 6,456,000 bales, whereas the United Kingdom with a spindleage capacity of 57,286,000 consumed only 3,121,000 bales of all kinds of cotton!

TABLE VI

Country	Mill Consumption of Cotton (Bales of 478 Pounds Lint, Except American, which are in Running Bales. 000's omitted)				
	1925–26	1924–25	1922–23	1923–24	1921–22
Total	23,940	22,642	19,982	21,325	19,990
United States (exclusive of linters)	6,456	6,193	5,681	6,666	5,910
Europe:					
United Kingdom	3,121	3,350	2,842	2,825	2,900
Continent	6,910	6,339	5,551	5,304	5,016
India	1,697	1,825	1,630	1,751	1,871
Japan	2,825	2,450	2,037	2,348	2,176
Canada	260	190	152	203	205
All other countries	2,671	2,295	2,089	2,228	1,912

There are two explanations for this apparent discrepancy. First is the fairly obvious one that there has been depression in Lancashire for several years, and while the number of spindles in place is rated about 20,000,000 more than in the United States, a large part of the mill equipment has been idle and effective capacity has not given a true measure of potentialities. In the United States, moreover, business has been relatively good in the textile industry in spite of depression in the New England mill districts. Another explanation and a more fundamental one is found in the fact that the United Kingdom's textile activities are confined more to the finer counts of yarns and finer grades of goods. Lancashire has many mills working exclusively on Egyptian cotton where the yarns run over No. 100, whereas among the Southern mills of the United States the average count of yarn probably does not run much above No. 20's. A spindle running on No. 100's would consume only about one fifth as much cotton as a spindle running on No. 20's.

A really extraordinary showing is made by Japan. Reference to Table VII discloses that in 1926 Japan is credited with 5,573,000 spindles. This is less than one tenth as many spindles as are credited to the United Kingdom. Yet Japan in the season of 1925–26 consumed 2,825,000 bales of cotton compared with 3,121,000 by the United Kingdom.

Here we have additional explanations. Japan not only spins

coarser counts of yarns with most of its active spindles in operation instead of a large proportion idle, but the hours of labor are much longer. Whereas in Lancashire many spindles in the last year or two, even when classed as active, have been worked on a thirty-four-hour basis weekly, Japanese schedules have called for one hundred hours weekly, and in some cases have run up as high as one hundred and twenty hours weekly. Japanese spindles, it will be noted, consume an average of about half a bale of cotton per annum, or about two hundred and fifty pounds, whereas Great Britain's total credited spindleage capacity shows an average output of only about one eighteenth of a bale, or somewhere around twenty-seven pounds yearly per spindle.

TABLE VII

WORLD'S COTTON SPINDLES (ACTIVE AND IDLE): 1926

Country	Cotton Spindles (number) (000's omitted)	Country	Cotton Spindles (number) (000's omitted)
Total	164,210		
		Europe — *Continued*	
United States	37,586	Netherlands	921
Europe:		Sweden	571
United Kingdom	57,286	Estonia	570
France	9,511	Portugal	502
Germany	10,480	Finland	255
Russia	7,246	Other Europe	682
Italy	4,833	India	8,510
Czechoslovakia	3,568	Japan	5,573
Spain	1,817	China	3,436
Belgium	1,854	Brazil	2,493
Switzerland	1,529	Canada	1,319
Poland	1,375	Mexico	830
Austria	1,032	All other countries	430

Cotton Manufacturing. Cotton manufacturing in the United States had its beginning in New England. The first small factory was built in 1787 at Beverly, Massachusetts, on the Bass River. On account of the inefficiency of its equipment, it was not a success. In 1790, Samuel Slater, a newly arrived Englishman, put up a plant at Pawtucket, Rhode Island, with machinery modeled after the plans of Arkwright. The operations were successful and the growth of the textile industry in New England from that time was

continuous and rapid. By 1810, the number of spindles in operation in the United States had reached 87,000. Two decades later, in 1830, more than 1,200,000 spindles had been installed with about 62,000 operatives and a product amounting in value to $32,000,000. The infant textile industry was fostered by protective tariff duties with the New England States giving strong advocacy to this policy.

Busy manufacturing centers sprang up throughout New England, New York, and Pennsylvania. Cotton manufacturing became the chief industry of many communities. Some idea of the growth of these enterprises may be obtained from the fact that in Bristol County, Massachusetts, there were in place in 1926 more than 7,500,000 spindles. Providence, Rhode Island, stood next with 1,718,000. Gaston County, North Carolina, took third place with 1,137,000 spindles.

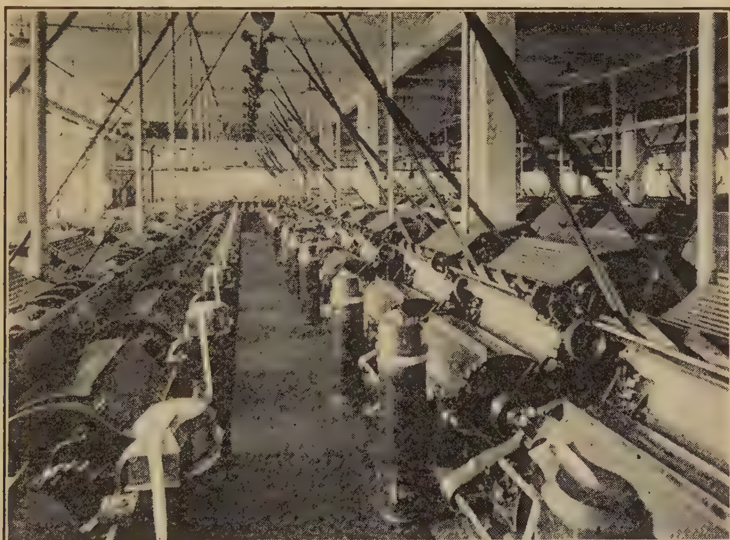


FIG. 4. —Carding room showing cans containing the "sliver."

The annual value of textile products increased by leaps and bounds, and the census report of 1910 placed the amount at more than $616,000,000.

Prior to 1900 the supremacy in cotton manufacturing from the standpoint of amount of cotton consumed was held by New England. Long experience in manufacturing, the training of

skilled employees, and abundance of water power that supplemented steam for driving machinery consolidated the position of the New England spinner.

A graphic picture of the competitive struggles between Northern and Southern mills is furnished by the figures given in Table VIII. The operations cover a range from 1840 to 1926 — by decades until 1900, and by five-year periods from 1900 to 1925. It will be noted that in 1840 the cotton-growing states were credited with only 180,000 spindles compared with 1,597,000 for New England. So far as spindleage is concerned, New England held the lead until 1925, when the cotton-growing states ran ahead with 17,292,000 spindles compared with 15,975,000 for the New England States.

In 1840, the Southern mills consumed 71,000 bales of cotton compared with 158,000 for New England. In 1900, the New England States consumed 1,909,000 against 1,523,000 for the cotton-growing states. The relative gain by Southern mills compared with New England after the beginning of the century is rapid. In 1926, the cotton-growing states are credited with a consumption of 4,795,000 bales compared with 1,671,000 for New England. The figures include linters.

The Southern cotton manufacturer has manifest advantages over his Northern rival. In the first place, his adjacence to cotton supply cuts down freight charges. His overhead is smaller for various reasons. He does not have to make as large expenditures to keep his plant heated. His local taxes are lower. One of the greatest hardships borne by the New England manufacturer has been the increasing levy for taxation, as the cotton manufacturing industry, being the leading enterprise in many localities, has been forced to carry the load for whole communities. The expenditures of many municipalities are being borne largely by imposts placed upon cotton manufacturers.

Labor legislation and labor agitation also have played their part in increasing operating costs. Weekly working schedules have been determined by legislative enactment, while operatives with their strong unions have forced wage scales higher. This presentation has nothing to do with the morals of the process. It is concerned merely with the economics of the situation. Obviously a manufacturer working on a forty-hour schedule weekly and with a payroll for employees in excess of a competitor operating fifty-four hours weekly is placed at a striking disadvantage.

It is true that living costs in New England centers are higher than they are in the South, and for this reason the operatives require a higher remuneration. In the South rents are lower, and it is possible in most mill communities for employees to maintain a kitchen garden and thus reduce their living costs to a considerable degree.

Recently, moreover, the development of hydroelectric power systems throughout the southern Appalachian district has provided Southern mill management with a source of cheap and efficient power that has greatly stimulated expansion. Some conception of the growth in the South may be obtained from the figures on spindleage increase even since 1920. In that year Gaston County, North Carolina, had 767,000 spindles in place and in 1926 the number had risen to 1,137,000. Spartanburg County, South Carolina, has grown from 853,000 to 946,000. Meantime Worcester, Massachusetts, which had 756,000 spindles in 1920, had dropped to 701,000 in 1926.

A broad picture of the comparative growth, giving spindles and cotton consumed, is furnished by Table VIII.

In order to present a clear picture of the cotton industry, the

TABLE VIII

	Cotton Consumed (Bales) (Linters Included) (000's omitted)				Active Cotton Spindles (000's omitted)			
Year	United States	Cotton growing States	New England States	All other States	United States	Cotton growing States	New England States	All other States
1926	7,259	4,795	1,671	792	34,750	17,574	15,525	1,650
1925	6,852	4,459	1,675	717	35,032	17,292	15,975	1,764
1920	6,762	3,714	2,418	628	35,480	15,230	18,287	1,962
1915	6,009	3,193	2,197	618	31,964	12,955	17,100	1,907
1910	4,798	2,292	2,016	490	28,266	10,494	15,735	2,037
1905	4,278[1]	2,140[1]	1,753[1]	385[1]	23,687	7,631	14,202	1,853
1900	3,873	1,523	1,909	440	19,472	4,367	13,171	1,933
1890	2,518	538	1,502	477	14,384	1,570	10,934	1,879
1880	1,570[2]	188[2]	1,129[2]	252[2]	10,653[2]	561[2]	8,632[2]	1,459[2]
1870	796	68	551	176	7,132	327	5,498	1,306
1860	845	93	567	184	5,235	324	3,858	1,052
1850	575	78	430	66	3,998	264	2,958	774
1840	236	71	158	6	2,284	180	1,597	506

[1] Does not include foreign cotton. [2] Cotton mills only.

facts and figures relating to the production and distribution of the raw material have been set forth in rather preponderant detail. We now come to an examination of the various processes involved in manufacture, including spinning, weaving, and "finishing," as well as the marketing of the completed fabric.

When cotton arrives at the mill the bales are weighed and inspected in order to determine whether the weights are in accordance with the invoice and the quality equal to the sample or the class set forth in the contract of purchase. Such bales as do not come up to specifications are put aside until the sellers have been communicated with, and the remainder, after being stripped of bagging and ties, are opened in the mixing room.

The preparatory processes in the up-to-date cotton mills have been made the subject of endless mechanical research and study. The importance of care in these preliminary operations is more pronounced, as the demand for better quality of cloth has become more pressing. The primary purpose of these preparatory operations is to clean the cotton thoroughly, removing all dirt, leaf, and other trash in so far as is possible, and to straighten the fibers so that maximum results may be obtained from the operation of spinning.

After the bale is broken up, it is pulled apart and the scattered pieces are fed into the breaker, from which it is then usually blown through large pipes from the room in which the bales are broken to the room in which the "willow" or "opener" is located. The purpose of this operation is to loosen the cotton and shake out the soil, dust, leaf, and other foreign substances. The "opener" removes the trash and also rolls the cotton into a more or less regular "lap." The fibers are still in a tangled mass lying close to each other and more or less curled up. Before the cotton can be spun into yarn it is necessary to remove the lighter impurities and straighten out the fiber through a combing process so that they will be parallel to each other.

As the cotton enters the "opener," it is seized by teeth fastened upon a large rapidly revolving cylinder and is flung by centrifugal force against a higher grid several times. Fans or suction produce a strong current of air blowing through the mass of fiber, helping to loosen the particles. The dirt comes out through the grid and is carried away, while the cotton after being carried around several times gradually works along a channel and comes out between

two large rollers which compress it into what looks like a sheet of cotton batting.

This sheet or " lap " is converted into a roll two or three feet in diameter and the cotton is then ready for the first doubling or blending process. In cases where tensile strength and evenness of yarn are especially desired, three or four of these sheets or " laps " may be fed through another opener known as a " scutcher," which again separates the sheets, mingling the fibers, removing more trash, and producing a more even " lap."

The next step in the process is in the carding room, where the " laps " are conveyed in up-to-date mills by mono-rail trolleys. In this department, the fibers are straightened, knots and practically all extraneous substances are removed. The basic purpose is the straightening out of the fibers by combing or brushing by means of wire brushes or cards. The device used today is the revolving flat card which has three main cylinders. The sheet of cotton first passes under the smallest one of these known as the " taker in," which is covered with fine saw teeth in one long strip of steel wound and fixed spirally on the surface of the cylinder. The " taker in " receives the cotton from a feed roller that turns above a smooth iron plate known as the " feed plate." The saw teeth comb the fibers out of the " lap," delivering the loose ones to a second cylinder, which is the largest of the set. This cylinder also has wire teeth bent at the same angle as the teeth in the " taker in." The cotton clings to the teeth and is carried around to the top of the cylinder, where it is seized by the teeth on the revolving flat card, which are bent in the opposite direction.

This portion of the carding machinery, generally known as " card-clothing," is arranged in strips placed crosswise on a moving lattice, going in the same direction as the cylinder but very slowly so that the fibers are carded between two sets of points. By this means the short fibers remain on the card wires of the lattice, while the long fibers, which are now lying lengthwise and parallel with one another, are carried over from the main cylinder to the " doffer " cylinder, the third member of the set. They are removed from the " doffer " cylinder by an oscillating comb, coming off in a light fleecy " lap " which is then condensed by means of a funnel into a soft rope about three quarters of an inch in diameter. This is known as " sliver." The " sliver " is then coiled into a can nearly four feet in height and eight inches in diameter. The carding

operation, it may be gathered, is quite complicated and one that is undertaken with the most scrupulous care and exactitude. On account of the necessity for removing the impurities, short and immature fiber, and arranging the perfect fibers in parallel fashion, the modern mill superintendent considers the carding operation the chief essential to the production of high-grade yarns and cloths.

The " sliver " is conveyed from the card with absolute precision in order to accomplish the coiling in the can and to prevent tangling as the rope of fiber passes from the funnel. The hole from which it emerges is off the center of a steel plate which revolves slowly, so that the " sliver " has an eccentric motion which causes it to fall into the can in regular coils.

A further step in the preparation of cotton for producing fine yarns consists of combing. This operation was first attempted about eighty years ago in Alsace, and has received general adoption where superiority of product is required. By the preliminary step in this operation, the " slivers " from fourteen to twenty cans are placed side by side, passing between three pairs of drawing rollers which reduce the size of the " sliver," and the entire number pass between two pairs of calender rollers from which is produced a " lap " about a foot wide. These " laps " are generally passed on to a ribbon lapper, where six are placed end on end and unrolled simultaneously, going between four pairs of drawing rollers, after which they are superimposed one upon the other, then going through calender rollers once more and finally coming out as a " lap " a little less than a foot wide. This process frequently is repeated several times, according to the quality of yarn required, as each drawing process straightens the fiber still more and lays the basis for still finer spinning. The " lap " in passing through this process is raked by fine-tooth combs with steel teeth set from sixteen to ninety per inch. This calls for breaking the " lap " again, and the efficiency of the comber depends on the mechanism it employs for joining the separated ends.

Six or eight " laps " go through the machines at a time, and the product once more is condensed in the form of " sliver " and deposited in cans.

The next stage of the process is technically known as drawing. The operation varies according to the type of yarn produced. For fine counts the " slivers " from the comber, and for the coarser grades that which comes directly from the card, are taken to the

drawing frame. The " slivers " from six or eight cans are fed through one opening and pass in combined form between several pairs of rollers so arranged that each succeeding pair revolves more rapidly than the pair that preceded it. The last pair in a series of four revolves six or eight times as fast as the first pair. This combination keeps pulling on the more or less irregular " slivers," tending to make them more uniform in diameter and density. The drawing frame usually consists of four or five " heads," and the " sliver," after it passes through one of these, is put through a

FIG. 5. — Top floor spinning room of a modern Southern mill.

second one along with other " slivers," so that the doubling and redoubling is a continuous process. The machines are equipped with automatic devices to cause instant stoppage when a " sliver " breaks either at the back or the front of the frame.

The " sliver " passes from the last head of the drawing frame to the " slubber," which not only continues the drawing and doubling, usually between several pairs of rollers, but, with the aid of a device that gives the " sliver " a slight twist, winds it upon a spindle. This is known as the " flyer," a piece of metal shaped like the letter " U," which revolving inverted over the spindle gives the thread a slight lateral turn as it coils on the spindle. The spindle also revolves, but at a continuing slackening rate so that the amount of twists may be kept uniform as the diameter of the coil upon

the spindle increases. The product then is known as "slubbing" instead of "sliver."

The "slubbing" is then passed in pairs between rollers and the product is less in diameter than that of the single "slubbing." The machine performs the function of combination, attenuation, twisting, and winding. This last drawing frame has more spindles than the slubber. This piece of equipment, except in the case of very fine yarns, is the roving frame similar to the last two mentioned, but containing more spindles. It receives the rovings from the intermediate frames, combining two into one and adding a little twist and winding the products on spindle tubes.

The details given above constitute most of the processes preliminary to actual spinning. It will be noted that merely enough twist has been given to hold the fibers together. They are still loose with practically no tensile strength.

In spinning there are two types of machines, the mule — an English product — and the ring, invented by James Thorpe, an American, in 1828, but not generally received on equal terms with the mule in this country until along about 1860. In this country the ring spindle outnumbers the mule spindle by nearly ten to one. In Great Britain there are about five times as many mule as ring spindles. The mule spindle receives its name from the fact that it performs two primary functions — spinning and drawing — at the same time, and is therefore regarded as a hybrid mechanism.

In mule spinning there is a long, wide machine carrying more than 1200 spindles, with drawing and twisting continuous although not consecutive. The twist first goes to the thin places where the least resistance is offered, and the carriage conveying the spindles continues to back away, the thicker parts of the thread being comparatively untwisted or pulled down to the average denominator and then twisted. The carriage holding the spindles usually runs back about five feet three inches. At the termination of the stretch the spindles increase their speed until the twist is completed and the carriage then starts on its return trip. This reverses the spindles and the thread which has been wound upon them is unwound. The slack is taken up by a guide wire, while another wire guides the thread to the winding point and winds it up in the opposite direction on the spindles. Consequently there is no slack when the round trip is completed.

The ring frame is not as impressive as the mule, but it is decidedly effective and works with amazing speed. The bobbins holding the roving are placed directly over the spindles. Around each of the latter is a ring. There are about 112 spindles on each machine, and all the machine rings for the spindles are fixed in one frame. The upper edge of the ring is flanged, and over the flange is a small C-shaped steel ring called the "traveler." As the spindles and the rollers revolve, the roving is fed out at a considerably slower rate than the spindle takes it up, so that there is always a tension on the thread. The spindle consequently pulls on the traveler, drawing it around on its flanged track. It revolves a little more slowly than the spindle, and thus the yarn receives its twist.

In ring spinning, it is possible to operate the spindles at almost unbelievable speed. The average is 10,000 revolutions per minute, and on fine yarns it is several thousand more. Speed is limited only by the ability of the operator to make splices when threads break, as well as the tendency of the traveler to fly off at excessive speed. The ring spindle is not only an American device, but it suits American methods. It spins continuously and produces about a third more yarn per operator compared with the mule. The mule-spun yarn, however, is more even and apparently has the call where exceptional quality is required. Labor costs, however, are lower with the ring spindle than with the mule.

The spools of finished yarn are placed upon a large frame called a "creel," having an average capacity of about 600 spools with sixteen to twenty on each tier. The threads from the spools are drawn between the dents of an adjustable reed and then under and over a series of rollers. They are then let down to the beam upon which they are wound. The revolving of the beam unwinds the yarn from the spools and winds it evenly upon the beam itself. There are devices for measuring the length of the warp that is wound and stopping the operation in case of breakage of thread or other accidents. The lengthwise threads of a fabric are known as the "warp" and the crosswise threads are known as the "weft," or "filling." The operation of the loom is too well known to require extended detail. The modern loom has automatic functions, such as stopping when warp or filling break or when the shuttles fail to cross the loom completely. The modern loom, which automatically removes the filling bobbins without stopping the loom,

is rapidly replacing the older types, and the labor saving thus resulting has effected remarkable economies.

After the manufacture of the cloth there are several other operations before the fabric can be placed upon the market. These processes consist of bleaching, printing, mercerizing, dyeing, and finishing. The fabric that comes from the loom is known as gray goods, and still contains many of the impurities of the fiber in its natural state and that have been picked up during its various processes through the mill. In bleaching the goods, several objects are

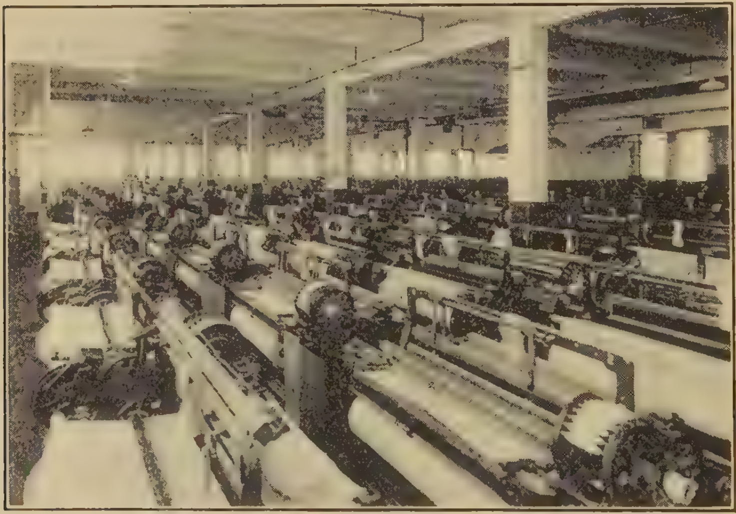


FIG. 6. — Weaving room of a large mill showing narrow looms in operation.

involved — removing the oily substances imbedded in the fiber as well as the elimination of dirt. Bleaching also tends to give a uniform whiteness.

The various processes consist of boiling in plain water; next, boiling in alkaline solution, then steeping in a bleaching solution and treatment in diluted sulfuric acid followed by thorough washing in a mild alkaline solution. These chemical treatments if properly conducted do not injure the strength of the goods. For certain classes of fabrics where a smooth surface is desired, it is necessary to resort to singeing before bleaching. This is done by passing the cloth stretched at full width very rapidly over heated plates or through gas flames so that the fuzz is singed off

without injuring the fabric itself. Other processes involved in finishing consist of dyeing, stretching, starching, glazing, and, in the case of certain goods, printing.

The marketing of textile products is one of the great merchandising branches of the country. There are large mill organizations that not only spin the cotton, weave the cloth, and finish it, but also have facilities for marketing their product. These, however, are only the very large organizations. Some of them, like the Amoskeag Manufacturing Company and the Pacific Mills, the Dan River and Riverside Mills and the Cannon Mills, make a variety of fabrics, while others specialize on a few products. Some mills confine themselves to spinning, while others buy yarns and do nothing but weave it.

A large part of the product of the cotton mills goes directly to drygoods jobbing houses, who sell it to retailers. Some goes directly to the cutting-up houses, which manufacture all kinds of garments, such as shirts, pyjamas, or overalls. One of the established instruments for disposing of textile products is the drygoods jobber who handles finished products, and deals in large amounts of gray goods. There is also the commission house that not only acts as seller for the mill, but frequently is interested in the corporation and nearly always helps to finance either accumulations of goods or purchases of cotton.

One of the largest buyers having direct contact with the mill or the commission house is the converter, who takes vast quantities of gray goods and puts them through the various finishing processes from bleaching to dyeing and final preparation for the market. A good deal of capital is needed by the converter, as the purchase of gray goods represents practically a cash operation, and a considerable quantity of fabrics may have to be carried through various finishing processes until the goods are marketed.

Most of the mills are represented in the great central goods markets — New York, Boston, Philadelphia, Baltimore, and Charlotte, North Carolina. Manufacturing corporations which have sufficient capital or credit to finance themselves frequently maintain their own selling offices and market their product in their own name to their own customers. The amount of capital required for conducting business in this fashion is very large, for it will be seen that this involves the purchase and accumulation of large quantities of cotton, the carrying of raw material through the various manu-

facturing and finishing processes, and last, but not least, the holding of the finished fabric until it is bought and paid for.

Many manufacturing concerns, both great and small, market their output through the drygoods commission house. This is an institution peculiar to the United States, and is ascribed to certain features of our banking methods that have prevented mills, even those with reasonably large capital, from obtaining the amount of direct banking accommodation necessary for their needs.

The operation of the commission house, the selling agent, is very clearly set forth in a most competent survey of the cotton industry in this country issued by the Guaranty Trust Company in 1919. The following outline is soundly descriptive of established selling methods:

" The commission house, in its usual relations with its mills, undertakes to conduct the sale of their products. Some commission agents insist upon having the entire selling control of all of the goods the mill produces, or at any rate, of all the goods of the kind which they are equipped to sell. Others, again, will take over a partial selling control of the product of a mill, and various lines of the same manufacturer may be found offering through different channels. There are some obvious disadvantages connected with this latter procedure.

" If the mill is a very large one, the selling agent may handle no goods except the product of that mill, but in the great majority of cases, the factor will represent a considerable number of mills.

" Immediately on receipt of the invoices of the goods consigned to the selling agent, the mill can draw against them a percentage of their value, previously agreed upon, usually about two thirds of their net selling price, and upon these loans interest at the rate of 6 per cent is charged. The difference between the rate at which the commission house can borrow money (in normal times perhaps 4 to 4½ per cent), and the 6 per cent which is usually charged to the mills, constitutes a considerable part of the profits of the factor's business.

" The factor often provides a store, together with a complete selling and office force, and every facility for receiving, storing, selling, shipping the goods, and for financing the business. The salesmen of the house travel throughout the country, reaching all the important markets; and the managers of the different depart-

ments, who thus understand the needs of the market, are in a position to advise the mill with intelligence and exactness as to the kind of goods which should be made to meet trade requirements. The cost of warehousing and insurance on the merchandise is also paid by the commission agent.

"The prices at which the goods are to be sold are fixed by the mill, but, of course, they will finally sell at prices determined by the market conditions. As the goods are sold, the amounts which they bring are credited to the mill, less whatever has been advanced against them. The selling agent also stands ready, no matter on what time and terms the goods may be sold, to credit the mill with the net value of the sale, less 6 per cent interest for the unexpired time within which the customer may pay, and from this interest charge also he secures part of his return. Of course if bank rates are very high, as they sometimes are for short periods, the factor may be out of pocket on the interest account, instead of making profit. As the goods are sold, so are the equities in them released, and the balance is credited to the mill. If, however, the goods sell at a loss there will be no equities coming to the mill; in fact, there are not infrequently deficiencies to make up.

"For these services, and according to the nature of the goods being sold, various commissions are charged, usually ranging between the limits of 4 and 8 per cent of the net returns of the sales. Plain unfinished goods which are marketed in large quantities are charged for at a relatively low figure; while fancy goods, sold in smaller quantities and requiring more effort and expense to sell them, are charged for at a higher figure.

"The selling agent also guarantees the credits of the firms to which he sells, so that no losses for bad debts can fall upon the manufacturer, but, at the same time, he will decline orders from any concerns except those with whose credit he is entirely satisfied.

"Not infrequently when the manufacturer conducts his own selling operations, he will use the facilities afforded by the commission house for the financial part of the business only, taking advances on his goods, having his sales cashed, and his credits guaranteed, etc. For these lesser services, of course, the commissions charged are smaller."

A summary of the present condition of the cotton manufacturing industry of the United States reveals a rather mixed but decidedly improving position. The ailments affecting the undertakings

may be largely ascribed to the tendency to overplant during the war and immediately after. Textile equipment is sufficiently large to take care of any amount of raw material that may be available after export needs have been satisfied. The operation of spindles and looms on capacity basis, particularly with the frequently detrimental practice of night running in the South, inevitably leads to overproduction. An attempt has been made to correct these evils through the medium of the newly formed Cotton Textile Institute, which has been organized to promote legitimate coöperation and to make available information and statistics that will give manufacturers a fairly correct picture of current conditions.

On account of the keen competition that has existed in the overplanted industry, there has been a tendency to sell goods below replacement cost, and only the more fortunate mill organizations — those who bought their raw material with exceptional judgment — have been able to make consistent profits. With the high prices for raw material that existed during 1923 and 1924, the rank and file of manufacturers steadily lost money, sometimes imperiling the surplus reserves. Resistance on the part of goods buyers prevented manufacturers from selling their output on a margin justified by the high cost of cotton. Many mills sold goods on the basis of twenty-five cent cotton when they were paying from thirty to thirty-five cents for their raw material.

Fortunately, with the larger crops of the last three seasons, there has been a gradual return to normal conditions. At present the cotton branch of the textile industry — generally speaking — may be considered to be on its feet. Goods buyers have been inclined to invest in the finished product, as they have felt that there was little risk in buying goods priced on an average of fourteen cents for the raw material.

It seems to have been clearly demonstrated that the cotton industry prospers best with an abundant supply of raw material at moderate prices.

Although cotton manufacturing constitutes one of the great industries of the country, ranking between fifth and eighth in value of products over a period of years, the nature of the operation does not make it susceptible to large and dominating combinations such as we find in steel, automobile manufacturing, copper production, and similar enterprises. It requires comparatively small capital to build and equip a plant and find a market for the output.

Goodwill such as may be acquired by turning out a superior product is not a permanent asset, although certain manufacturers in former days placed themselves in a favorable position through the quality of goods manufactured by them. The classic instances were "Fruit of the Loom," Amoskeag ginghams, and Utica sheetings.

Speaking broadly, however, there would appear to be little prospect of making combinations such as exist in other great industries that would give such organizations undeniable advantage. Competition is bound to be keen so long as cheap power may be obtained, modern textile machinery bought, and raw material purchased on an attractive basis.

CHAPTER VIII

THE ELECTRIC INDUSTRY

By L. A. Osborne [1]

On September 4th, 1821, Michael Faraday, at the Royal Institution, London, tied a magnetized needle by one end to the bottom of a cup and poured in sufficient mercury to float the little magnet upright with its upper half protruding. Then he lowered a vertical wire until it touched the center of the mercury pool, and connecting wire and mercury to a battery, sent an electric current through them. Instantly the magnet began revolving round and round the wire and continued to do so as long as the current was kept flowing.

It was a beautiful experiment and a veritable scientific triumph. Scientists had believed for some time that it was possible to produce continuous motion from the interaction of a magnet and a conductor carrying an electric current, but no one had been able to accomplish this feat until Faraday conceived the idea of subjecting only half of a magnet to the influence of the current — and then the thing was done.

In that little cup the electric industry was born; for here was demonstrated for the first time the interchangeability of electrical and mechanical power, the basis of all electrical development.

Much was known about electricity and magnetism prior to Faraday's time. Lightning had been identified with the electric spark; the electric battery, the arc light, and the electromagnet had been discovered; water and other chemical compounds had been decomposed by the electric current; and many of the fundamental electrical laws had been laid down.

But nothing in all this was of practical value. Its sum total was as remote from the life of the public at large as our information concerning stellar constitution and evolution is today.

[1] Vice President of Westinghouse Elec. and Mfg. Co., assisted by W. H. Easton.

Faraday's genius changed all this. His interest seized upon this mysterious scientific curiosity, and when his work with it was done, the way was open for its transformation into a useful servant of humanity.

Not only did Faraday discover the important principle of electromagnetic rotation and later develop from this the embryo of the modern electric motor, but he realized that in doing so he had solved but half a problem.

"If an electric current flowing through a conductor can make a magnet move, is not the reverse also true?" he reasoned. "Will not a magnet moving past a conductor cause an electric current to flow?"

The Birth of the Generator. For ten years he wrestled with this proposition. As a matter of actual fact, the various little motor devices that he constructed were capable of furnishing the desired proof, but he lacked apparatus of sufficient delicacy to gain knowledge of this fact.

On September 23, 1831, he wrote to a friend: "I think I have got hold of a good thing but can't say. It may be a weed instead of a fish that, after all my labour, I may pull up."

To the average observer, the thing thus hooked would have appeared weedy indeed. All that it amounted to was the discovery that when a magnet was thrust into or withdrawn from a coil of wire, a needle on an instrument connected to the ends of the wire moved slightly.

But the great scientist knew a fish when he saw one, in spite of his cautious phraseology. He had at last solved the second half of the problem — he had generated an electric current by means of a moving magnet. Shortly thereafter his expert fingers fashioned a little rotating apparatus which when turned gave out an electric current continuously, and the principle of the electric generator was given to the world.

Immediately thereafter, research and experimentation with the object of applying electricity to practical ends began, and has continued without ceasing ever since.

A generation was to pass, however, before electrical equipment of real utility (excepting the telegraph) was to be produced. For forty years workers in the electrical field were to struggle and fail. But by 1870, a practical generator made its appearance (largely as the result of the work of Z. T. Gramme, of Belgium), and it

was quickly applied to the operation of crude arc lamps which were used in certain British lighthouses and for illuminating the Place de l'Opéra in Paris. Then an American electrical inventor appeared upon the scene; and from that time on the United States has been predominant in electrical development.

The Arc Lamp. In 1878, Charles F. Brush, a young chemist of Cleveland, Ohio, who spent most of his spare time playing with electric batteries, devised a really workable arc lamp and an ingenious form of generator for supplying a series of these lamps with current. At about the same time, Edward Weston, of Newark, N. J., and Elihu Thomson, of Philadelphia, Pa., achieved success in this same field, and before 1880, blazing arcs (installed chiefly for advertising purposes) were conspicuous in several of our larger cities.

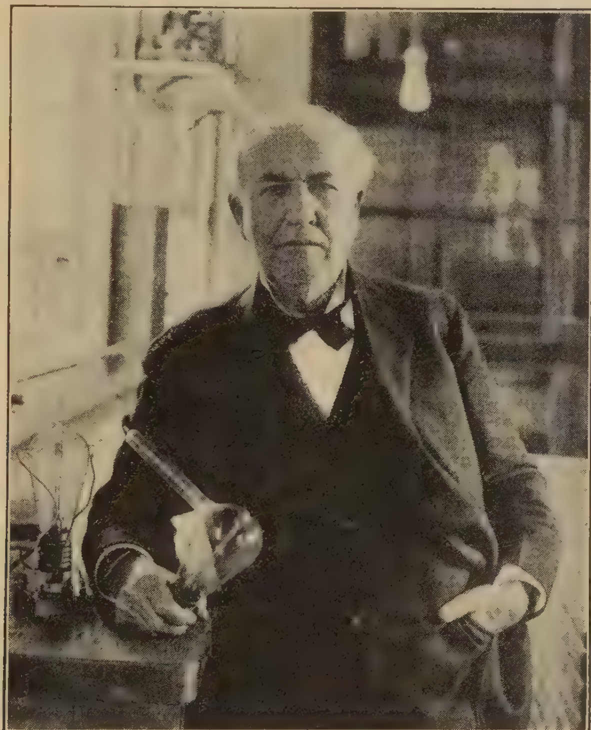
The Incandescent Lamp. This intense light was a challenge to other inventors. Though suitable for outdoor use, it was entirely too brilliant for indoor illumination, and a number of investigators, including Edison, Sawyer, and Man in the United States and Fox and Swan in England, set about solving the problem of "subdividing the electric light."

On a day now famous in electrical history, October 21, 1879, Edison produced a successful incandescent electric lamp, and by the end of 1882 he had started to provide a market for it by building on Pearl Street in New York City a central station to furnish electric power for public use.

The First Central Station. It is probably no exaggeration to say that this station was this great inventor's greatest achievement. Not only was it the foundation of the United States electric light and power business, which in 1926 was capitalized at over $8,000,000,000 and furnished 68,000,000,000 kilowatt-hours of power, but it was an engineering accomplishment of the highest order.

Its builder had no precedents to guide him. Practically everything that went into it pertaining to the generation, distribution, and use of the power had to be conceived, designed, constructed, and installed by himself and his associates, and operated by men trained by them. That so novel a creation should operate satisfactorily on the day it was opened, and remained in operation without serious interruption thereafter, constitutes a record unparalleled in engineering annals.

The advantages of the electric lamp over the other illuminants of that day were quickly recognized and its use spread rapidly. Power stations were established in scores of cities within the next few years, and numerous "isolated" plants were installed to serve large buildings, factories, and ships.



Brown Brothers

FIG. 1. —Thomas Edison in his laboratory.

Thus, electricity was at last made the servant of humanity, but it was not yet ready to put forth its full powers. The Edison system had a distinct limitation which had to be removed before electrical development as we know it today became possible.

The Limitations of Low-Voltage Current. In this system, direct current was generated, distributed, and supplied to the consumer at 220 volts. This voltage was selected because it corresponded to the technical requirements of the incandescent lamp, but it re-

stricted the distance over which the power could be economically sent. The cost of transmitting power at this low voltage rises very rapidly with the distance, so that it is, in general, cheaper to build a new station than to supply a given district with 220-volt power from a station a mile or so away. Thus, to serve the entire city of New York with 220-volt electricity, a dozen or more central stations would be needed.

This limitation was understood by all electrical engineers, but the great majority felt that it was inherent and irremediable, like the limitation to the transmission of power by belts or ropes. Others, however, among whom was George Westinghouse, inventor of the air brake, thought otherwise.

Westinghouse was one of the pioneer workers in the electric power field. He used electricity for the operation of railroad signals and he also built some of the first electric-lighting generators. But he does not seem to have become especially interested in the new power until he saw an opportunity for improving it radically by removing the distance limitation due to the use of low-voltage current.

To this end, he and his associates carried out numerous experiments and he also bought many patents and ideas that appeared to have bearing on the matter.

The Alternating-Current System. Among his purchases was the "secondary generator" system of Gaulard and Gibbs, which had been widely heralded in Europe as making possible the long-distance transmission of electricity; but his disappointment must have been keen when, on receipt of the actual apparatus, he discovered it was impractical because it was not self-regulating.

However, it did contain the germ of a promising principle (based, by the way, on another one of Faraday's electrical discoveries), and with the active aid of William Stanley, he developed an entirely new electric power system — the alternating-current system.

The outstanding feature of this system is that the voltage of alternating current can be raised or lowered to any desired value by means of very simple and highly efficient apparatus. To serve, for example, a point several miles away from the power house, electrical energy can be generated at, say, 500 volts, transmitted at, say, 3000 volts, and consumed at the safe value of 110 volts. This

voltage flexibility of the alternating current system permits large areas to be served from a single power house and power to be drawn from distant waterfalls.

The first experimental alternating-current lighting plant was put into operation at Great Barrington, Mass., in the spring of

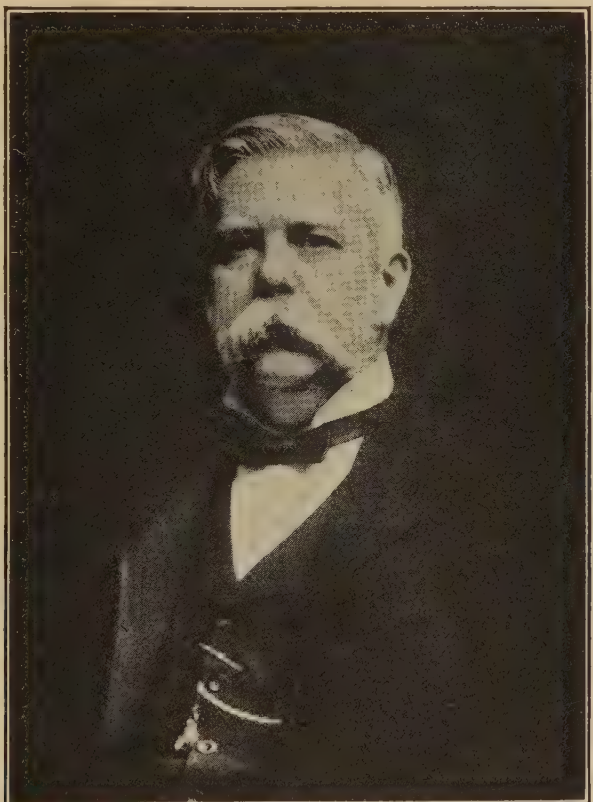


Fig. 2. — George Westinghouse.

1886, and the first commercial plant was installed in Buffalo in the fall of that same year.

The Battle of the Systems. The appearance of this new system precipitated what is known as the "Battle of the Systems," a lively and often acrimonious commercial contest which lasted until the Chicago World's Fair, of 1893. This exhibition was conspicuous for its many amazing electrical effects, and since all

were produced by alternating current, its opponents were forced to capitulate.

Electrical engineers then began to combine the two systems so that the special virtues of each could be used to the best advantage, and this was the beginning of electrical development as we know it today.

At present, over 95 per cent of the electrical energy consumed in the United States is generated and distributed as alternating cur-

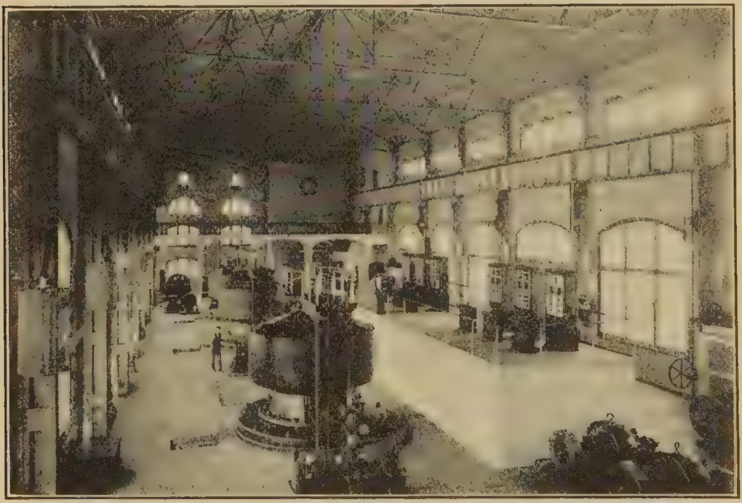


Fig. 3. — 5000 H.P. 2-phase generators, Niagara, New York.

rent, but a considerable proportion of the total is transformed into direct current for electric railways, electrochemical industries, and other special applications.

Harnessing Niagara Falls. In 1895 occurred one of the outstanding events of the electrical industry, for in that year was placed in operation the first of three 5000-horsepower alternating-current generators which were driven by power derived directly from Niagara Falls.

Inasmuch as these machines were several times larger than any power-generating machines ever before built and they delivered power to Buffalo, at the then unheard-of distance of 20 miles, many people gained from this undertaking their first conception of the possibilities that lay in electrical development.

In addition, it stimulated activity in the use of waterpower.

Waterpower had been previously employed for generating electricity, Edison having installed a small water-driven plant at Appleton, Wisconsin, as early as 1882; but the great alternating current installation at Niagara formed the basis of a new order of hydroelectric development, and by 1912 over 4,000,000 horsepower of waterpower was in use by American public utilities.

Progress in this direction halted, however, because it was found that the Federal laws, which, for one reason or another, applied to a large proportion of the total 50,000,000 potential horsepower of waterpower in the United States, were adverse to the commercial development of these powers. A great deal of study was given to this subject by engineers, government officials, and legislators for several years, and in 1920 a Federal Water Power Act was passed, which eliminated the most serious obstacles in the way of waterpower development. This development is now going forward as rapidly as economic conditions justify.

The Steam Turbine. Hardly had the revolution in waterpower engineering due to the Niagara installation taken place than an equally momentous one occurred in the steam-power field. In 1884 Charles Parsons, of England, using a principle known to the ancient Greeks, invented the rotating type of steam prime-mover called the steam turbine. Westinghouse, seeing in the rapidly and uniformly revolving shaft of the turbine the ideal means for driving electric generators, bought the American rights in 1896 and proceeded to build turbine-operated generators.

It was a fortunate coincidence (or perhaps it was the result of keen foresight) that this new type of engine should have been made available at this particular time, for the limit in the size of the standard reciprocating engine was being reached. In fact, in 1899 there were built for the New York Subway seventeen 10,000-horsepower reciprocating engines, which, in the opinion of many engineers, were about the largest of this type that ever could be constructed.

These magnificent machines towered forty feet above their massive concrete foundations and were so splendidly designed and constructed that they were capable of operating for at least a century with unimpaired efficiency. Yet within three years they were obsolete, their work being done by high-speed steam turbines of only one tenth their size.

With the general introduction of the steam turbine, steam-power plants rapidly increased in size and improved in efficiency. Turbo-generator units of 100,000 horsepower capacity are in operation and one of over 200,000 horsepower capacity is under construction. But even larger ones can be built. As to efficiency, some modern steam-turbine plants produce a kilowatt-hour of power on a pound of coal, whereas the best of reciprocating engines require two or three times as much. Largely to the turbine, therefore, belongs the credit for the immense amount of low-cost electric power that is now being supplied to users in the United States.

Superpower. War, which changes many things, brought far-reaching changes to the electrical industry.

The original electric power plants of the United States were naturally located in areas of dense population, where there was ample demand for their service. Each gradually extended its operations until it covered its particular community, but few sent lines very far out into the sparsely populated surrounding districts because the small amount of business thus secured did not justify the necessary construction work. Hence, in 1917, there were in the United States several thousand separate and independent power systems, confined for the most part to cities and towns, while vast intervening areas were without power service.

As soon as the United States entered the World War, a tremendous increase in the demand for power took place in many localities, due to the needs of the factories engaged in supplying war materiel. In certain industrial centers, the demand for power soon exceeded the supply, and there was grave danger to our war program because much-needed supplies were being delayed.

The engineers of the War Department studied this situation and found that, in many cases, there were adjacent to the overloaded power systems other systems with more or less reserve capacity, and they suggested that if the latter could be connected with the former, thereby pooling the entire supply for each region, sufficient power to supply the most pressing needs could often be secured. The sudden ending of the war made it unnecessary to carry out this suggestion as a military measure, but the electric industry, which had already worked out this plan for other reasons, went ahead with it.

The gains secured by the interconnection and integration of

previously independent electric power systems can be summed up as follows:

Large and efficient steam plants can be substituted for numerous small and less efficient ones; the large plants can be placed in the best available locations with reference to fuel supplies and cooling water; waterpowers, formerly too remote or too large for development, can be connected into the system, thereby saving fuel; greater reliability of service is secured, due to the fact that since power is supplied from several independent sources, the shutting down of one plant or a break in the line does not interrupt power service.

Because of these and other advantages, the interconnection of power systems has proceeded with great rapidity in the last few years, with the result that power lines are crossing the country in every direction. It is not, indeed, too much to expect that in the near future practically every habitable part of the United States will receive power service, including a large proportion of our 6,000,000 farms which are today without it.

The Electric Railway. In the early days of the electric industry, electricity was used almost exclusively for lighting. It is said that an executive of an electric light company, on learning in 1888 that electricity had been substituted for gas in practically all of the business buildings of his city, resigned because he thought there was no more business in sight. But the leaders of the electric industry were not of this man's mind Even before the first electric light plant had become a reality, they foresaw that electricity would do much of the world's work. Curiously enough, however, the first worker to find relief through electric power was the horse.

Several inventors claim to be the originator of the electric car, and many cities take pride in being its birthplace, but the truth of the matter is that the idea of electric traction has fascinated inventors ever since the days of Faraday. As early as 1835, Thomas Davenport, a Vermont blacksmith, operated a small vehicle by means of electric batteries at Springfield, Mass., and since that time hardly a year passed without the demonstration of some new electrically operated car, carriage, or locomotive. However, among the first electric traction systems to remain continuously in operation appear to be those installed in Binghamton, N. Y., in 1886 by Leo Daft, and in Richmond, Va., in 1887 by Frank J. Sprague.

The workers in this field had to solve many perplexing problems before a really operative electric car could be produced. Those who have had no experience in the development of a new art have little conception of the difficulties encountered. For example, it is said that over fifty different kinds of current collector were tried out before the familiar trolley pole with its little under-running wheel was hit upon by C. J. Van Depoele. Incidentally, the patent on this simple device proved to be one of the most valuable ever issued, as it gave its possessor virtual control of the electric railway industry as long as it remained in force.

The electric railway appealed very strongly to the American public, and development took place rapidly after all technical difficulties were overcome. By 1902, there were 22,500 miles of electric urban and interurban railways in the United States; and by 1912, there were 41,000 miles. In recent years, the growth of automotive transportation has restricted electric railway growth, but the trolley car still remains by far the best means for carrying large numbers of people rapidly and safely in towns and cities.

Railroad Electrification. Steam railroad electrification developed directly from street railway practice, and the first railroads to be electrified — including the Baltimore and Ohio at Baltimore, the Lackawanna and Wyoming Valley, the Long Island, the New York Central, and the Pennsylvania at New York — were operated by means of standard street railway power, 600-volt direct current, supplied by a third rail.

Experience with this system has proved that while it is satisfactory for a railroad like the Long Island, which is naturally isolated and has short runs, it is not suitable for heavy, long-distance traffic.

In 1907, the New Haven Railroad was electrified, using 11,000-volt alternating-current, supplied by a trolley wire, and this system has been adopted by practically all U. S. railroads electrified since then; among which are the Pennsylvania at Philadelphia, the Norfolk and Western, the Virginian, the Detroit, Toledo and Ironton, and the Great Northern. The conspicuous exception is the Chicago, Milwaukee and St. Paul, which uses 3000-volt direct current.

The chief reason why electricity is being substituted for steam for railroad operation is that it increases the traffic-carrying capacity of existent tracks, right-of-way, and other facilities. This

is due to the increased flexibility of electric operation and the higher powers that can be applied per train.

For example, to reverse the suburban trains which run into the dead-end terminal of Broad Street Station, Philadelphia, seven movements were required under steam operation, whereas under present electric operation, they merely run in and then run out again. This simplification of operations more than tripled the capacity of this station.

For power application, the Virginian Railroad is an outstanding case. The enormous coal trains of this railroad are hauled up the steep grades by electric locomotives which apply as much as 22,500 horsepower per train, or nearly three times the total power possible with steam operation. In consequence, longer trains can be operated at much higher speeds, and the traffic capacity of the electrified section is more than doubled. The alternative, with the use of steam power, was to add more tracks, which would have involved almost prohibitive expense.

While the Virginian locomotives are at present the most powerful in the world, larger ones can be put in service, provided, however, the strength of the rolling stock is increased so as to withstand the tremendous stresses.

But in spite of these advantages, railroad electrification has not progressed very rapidly in the United States, less than 3 per cent of the present mileage being at present electrically operated. This is due largely to the fact that, because of adverse public attitude and the difficulties arising from government operation during the war, the railroads have been unable to finance major improvements. There are indications, however, that this situation is changing, and it is probable that the next generation will see about 75 per cent of our rail traffic electrically hauled, although this will not mean the electrification of more than about 50 per cent of our total mileage.

The Electrification of Industry. Electric traction has meant much to the nation, but there is another application of electric power which, though the general public is hardly conscious of it, has produced results of even greater importance. This is the use of electric power for manufacturing purposes.

From the very earliest days electric motors were used for driving various machines, such as elevators, pumps, fans, printing presses, machine tools, etc., but it was not until after Nikola Tesla invented

a simple and reliable alternating-current motor, in 1888, that electric power began to find general use in industry.

At first a single motor was substituted for a steam engine to drive groups of machines with the object of securing a slight reduction in the cost of power. But as the knowledge and skill of motor designers increased and the various manufacturing processes were more closely studied, it became evident that much could be gained by designing motors with special speed, power, and mechanical characteristics, and in many cases with special controllers, to fit the particular requirement of each kind of industrial machine.

Thus, textile machines are preferably driven by motors of rigidly constant speed in order to turn out maximum amounts of uniform product; machine tools require motors capable of speed adjustment, but on each step the speed much be constant regardless of the load; crane and hoist motors must also be capable of speed adjustment, but in this case the speed should vary with the load so that light loads are handled more rapidly than heavy ones; light weight is essential for motors driving portable drills; and motors for use in chemical factories must be of non-corrosive construction. In this manner, hundreds of different applications have been analyzed from a motor-drive standpoint.

It took many years to work out the details in full, but the use of electric motors by American industry is now general. The result has been an astounding increase in production per worker, and the gaining of the world's industrial supremacy for the United States.

It is estimated that, due to the general use of electric power in industry, the average American workman has at his disposal about 4 horsepower of power, which is more than twice the British figure, and is still larger than the power available to workers in other nations. Calculations of average rates of wages show that the earnings of workers in the different countries vary directly in accordance with the amount of power used, and it is practically certain that the high standard of living enjoyed by the American workers is due largely to our extensive use of electric motive power.

Electricity is also being used in industry in two other ways, for electrochemical processes and for heat treating.

The electrochemical industry was greatly stimulated when a large amount of cheap electric power was made available at Niagara

Falls, and there sprang up at this point numerous factories devoted to the manufacture of aluminum, graphite, abrasives, chlorine, alloys, and other materials in the manufacture of which the use of electric power is an essential factor. From a mere tourist's stopping point, ignored by the U. S. Census, in 1890, the municipality

By Ewing Galloway, New York

FIG. 4. — The white lights of Broadway.

of Niagara Falls grew in 25 years to a city of 51,000 population, with electrochemical products totaling nearly $100,000,000 annually.

The use of electric heat for the various industrial baking and treating processes is a fairly new application, but it promises in time to be as widespread and as important as the use of electric motive power. The high finish of many of our automobiles and the excellent quality of the metals used in them are examples of the efficiency of electric heat.

Electricity in the Home. Just as electricity in industry has immensely benefited the American workman, so, it is believed, will the growing use of electrical domestic devices help the American housewife.

As far back as January 3, 1880, Edison mentioned in an inter-

view that an electric motor, "two feet long and weighing 80 pounds," could be used for driving a domestic sewing machine, but it was not until a practical electric flat-iron was introduced many years later that feminine fancy was actually caught.

Even after the electric iron achieved popularity, it was many more years before any other electric household appliance enjoyed substantial sales, so conservative is womankind towards innovations. Today, however, some hundred domestic heating, cooking, and motor-driven devices are available. The electric refrigerator is the most recent appliance to secure acceptance, and the automatic electric controlling and feeding mechanism for coal or oil furnaces is just beginning to come into prominence.

The importance of household devices from an electric industry standpoint lies in the immense market they offer, both as articles of merchandising and as consumers of power. In 1926, the total sales of electrical merchandise amounted to approximately $800,000,000, or almost half the total sales of electrical goods, but it is estimated that at least ten times that amount could have been sold without saturating the present market.

Electric Power Goes to Sea. Though by 1912 electricity was becoming dominant on land, steam still reigned supreme at sea. Electric lighting was in general use on vessels, but electric power was generally regarded by marine engineers as utterly unsuited to their peculiar requirements.

Largely through the efforts of W. L. R. Emmet, electric power made an impressive entrance into the marine field in 1913. In that year was placed in commission the U. S. naval collier, "Jupiter," which was equipped with electrical propelling machinery supplied with power from steam turbine-generators. The "Jupiter" was entirely successful, showing excellent navigating qualities and a fuel economy that was 25 per cent better than other vessels of her class operated by reciprocating engines. These advantages, as well as certain military considerations, led the U. S. Navy Department to standardize on steam-electric drive for battleships, and our present fleet contains six electrically propelled super-dreadnaughts.

Though the record of this electric fleet has been admirable in every respect, steam-electric drive has not been used to any great extent on merchant vessels, although it is usually regarded as ideal for the largest type of passenger liners. A modified form

of this drive, however, in which the Diesel oil engine is used as the prime mover, has found acceptance for certain types of vessels, such as tugs, fire boats, ferries, dredges, and others where either rapid maneuvering power or the elimination of stand-by losses, or both, are of importance.

The oil-engine electric drive is being installed on most new vessels of this type and is also gaining headway for ocean-going and lake-going freighters, tankers, and passenger ships.

Aside from the propelling machinery, electrical apparatus is being rapidly introduced for performing all other work on shipboard, such as cargo-handling, steering, pumping, ventilating, anchor-handling, etc., and in time few vessels will have auxiliary machinery of any other kind.

Electricity on the Farm. There remains one very important field of American industry which is so far practically unelectrified; namely, agriculture. At present, only about $3\frac{1}{2}$ per cent of our farms are receiving electric power from central station lines. This, however, is due to the fact that until recently farms were usually quite remote from power lines; but the superpower developments of the past few years are rapidly changing this situation. One authority on electricity in agriculture states that over a million United States farms will be receiving electric power by 1935.

The history of electrification in the manufacturing industry may be expected to repeat itself here. After electric power is available to our farms in ample supply and apparatus is designed specifically for farm work, our farmers will undoubtedly be able to raise their earning capacity by the use of this power, precisely as have our industrial workers.

Radio Broadcasting. After having penetrated into all existing fields of human activity, the electrical industry proceeded to startle the world by creating an entirely new industry.

Radio broadcasting is indeed the modern miracle. Not only are its accomplishments almost unbelievable, but the rapidity of its growth as a commercial enterprise is unparalleled. In less than five years, the annual sales of radio apparatus in the United States rose from a few hundred thousand to over five hundred million dollars.

Very shortly after Fessenden and others, in the early part of the present century, found means for projecting their voices into

space without wires, a number of professional and amateur enthusiasts began building radio telephonic transmitting and receiving apparatus, and soon the ether was transmitting sounds of every description.

The object of these " broadcasters " was purely scientific. Interest was centered in improving radio technique, and a typical procedure was to play a given phonograph record, make a change in the " hook-up," repeat the record, make another change, repeat again, and so on ad infinitum, while friendly listeners sent in reports as to the results of the different changes.

One of the members of this radio brotherhood was Frank Conrad, of Pittsburgh, assistant chief engineer of the Westinghouse Electric and Manufacturing Company, who built so excellent a transmitting station after the war restrictions on radio operation were removed, that it soon became famous in radio circles. The nights on which Conrad transmitted became red-letter ones to his confreres, and as the result of much urging, he began to announce the dates of his transmissions in advance and to send out special request programs.

The interest that Conrad's hobby had aroused came at length to the attention of Harry P. Davis, vice president of the Westinghouse Company, who conceived the idea that here was a medium which, if properly organized and developed, might be employed for the entertainment, information, and education of the general public.

He immediately put his idea into execution and on November 2, 1920, he had broadcasted from a powerful radio station, installed at the East Pittsburgh Works, and later given the call letters KDKA, the returns of the Harding-Cox presidential election.

The letters received as a result of this experiment showed that there was a good-sized radio audience in existence and that this audience was keenly interested in the new undertaking. As a result, KDKA, the pioneer radio broadcasting station, was soon put into daily operation, which has continued ever since.

For about a year KDKA was the only true " broadcasting station " in the world, and in that time it originated almost every feature that finds a place in broadcasting today, including prearranged and pre-announced programs, the employment of announcers, the construction of a special studio, and the picking-up of important outside features, such as church services, concerts, sporting events, and addresses.

In the fall of 1921, the Westinghouse Company opened WBZ, at Springfield, Mass.; WJZ, Newark, N. J.; and KYW, Chicago; and before Christmas of that year, the east went radio mad.

Other broadcasting stations quickly made their appearance, and by the fall of 1922 radio broadcasting as a new art and a new business was in full swing.

At present the technical side of radio has been so well developed that broadcasts from KDKA have been received and rebroadcasted in South America, Australia, and South Africa, and it is within the bounds of engineering possibility for a person speaking anywhere in the world to be heard by every human being in the world.

Attention is now being chiefly directed to the development of the artistic side of radio broadcasting, with special reference to the improvement of programs and the bettering of tone qualities; but engineers are busily working on other problems, such as television, which, if attainable, will make the miracle of sound projection appear second-rate indeed.

Electrical Manufacturing in the United States. The history of electrical manufacturing in the United States during the first decade of electrical development is largely the history of the two great existing manufacturing companies — the General Electric Company and the Westinghouse Electric and Manufacturing Company — since many of the leading pioneer manufacturers were eventually absorbed by one or the other of these two organizations.

Among these pioneers were the Edison Machine Works and several other Edison companies, the Sprague Electric Railway and Motor Company, the Thomson-Houston Electric Company, the Brush Electric Light Company, the Van Depoele Company, the Consolidated Electric Company, the United States Electric Lighting Company, and George Westinghouse, who carried on his early electric work as a personal undertaking. All of these companies were active and progressive, and each was headed and inspired by a leader of unusual ability.

In 1890, the situation was as follows: The Edison electric machinery manufacturing interests had been combined and had absorbed Sprague's organization to form the Edison General Electric Company, with a factory at Schenectady, N. Y.; the Thomson-Houston Company had absorbed the Brush Company, the Van Depoele Company with its valuable trolley patent, and several others, and had extensive works at Lynn, Mass.; and Westing-

house had formed the Westinghouse Electric and Manufacturing Company, at Pittsburgh, from an earlier Westinghouse Electric Company, the United States Lighting Company, and the Consolidated Electric Company, which owned the Sawyer-Man incandescent lamp filament patent.

Thus there were three chief competitors in the field, two of which, Edison and Thomson-Houston, were working in closely parallel lines, while Westinghouse stood somewhat apart, due to its adhesion to the alternating-current system.

In 1892, C. A. Coffin combined the Edison and Thomson-Houston interests to form the General Electric Company.

While the General Electric and the Westinghouse Companies have ever since that time retained their position as leaders in the United States electrical manufacturing field, they have never been free from active competition. At all times there have been from several hundred to a thousand smaller electrical manufacturers who, though individually specializing in a limited number of lines, as a group cover practically the entire field.

This situation has been an exceedingly fortunate one, both for the electrical industry and for the American public. On the one hand, there are two large competitors, with wide experience and extensive resources; and on the other is a group with the advantages of low overhead costs and the concentration of effort upon specific developments. The result of this alignment has been to stimulate research, develop new services, improve quality, and lower costs, and this is one of the important factors in America's electrical leadership.

Financial History of General Electric Company: 1892–1926. General Electric Company was incorporated April 15, 1892, as a consolidation of Edison General Electric Company and Thomson-Houston Electric Company. These were acquired in exchange for $30,359,700 common and $4,251,900 preferred stock. $100,000 common stock and $10,000,000 5 per cent debenture bonds were sold for cash.

The financial depression of 1894–98 led to a suspension of dividends, and in the latter year each class of stock was reduced 40 per cent. Payment was then made of all cumulated dividends on the preferred stock. Dividends on the common stock were resumed in 1899 and have since been paid without interruption or decrease.

The preferred stock was retired in 1901 by exchange for common

stock. In the following year, the common stock was increased by a $66\frac{2}{3}$ per cent stock dividend, thus offsetting the reduction of 1898. A further stock dividend of 30 per cent was paid in 1912.

Additional common stock has been issued at various times since 1900 for cash, for stock dividends, for redemption of bonds, and for properties acquired.

Beginning with 1901, the company paid cash dividends at the rate of $8. From 1918 to 1922 an additional 2 per cent was paid semi-annually in common stock. The rate of stock dividend was increased in 1922 to 5 per cent, payment then being made annually in special stock. This special stock is entitled to a fixed dividend rate of 6 per cent.

Each share of the $100 par common stock outstanding in 1926 was exchanged for four shares of new, no par common stock, upon which the Company is paying dividends of $3 per annum in cash and $1 in special stock.

The only funded debt outstanding at December 31, 1925, was $2,047,000 gold debenture bonds. These $3\frac{1}{2}$ per cent securities were issued in 1902 in payment for property acquired.

A summary follows:

G. E. COMPANY

(from annual reports)

Fiscal Year Ended	Capital Stock		Dividend Rate		Sales Billed	Surplus
	Preferred	Common	Preferred	Common		
Jan. 31, 1893	$4,236,900	$30,426,900	$3\frac{1}{2}$%	6%	$11,728,000[1]	$1,024,954
Jan. 31, 1901	2,551,200	21,400,300	7	8	28,783,275	6,629,181
Jan. 31, 1906	Retired	54,286,750		8	43,146,902	12,027,295
Dec. 31, 1910		65,179,600		8	71,478,557	23,022,706
Dec. 31, 1915		101,510,600		8	85,522,070	23,692,871
Dec. 31, 1920		141,880,316		8 cash 4 stock	275,758,488	70,048,611
Dec. 31, 1925	35,718,875[2]	180,287,046	6[2]	8 cash	290,290,166	85,848,171

[1] 8 months from June 1, 1892. [2] Special.

Financial History of the Westinghouse Electric and Manufacturing Company. The company began business in 1886 as the Westinghouse Electric Company. In 1889, the charter of the Chartiers Improvement Company, which was incorporated in 1872 with a capital of $50,000, was purchased, and the name of this company changed to Westinghouse Electric and Manufactur-

ing Company and its capital increased to $2,500,000. The Electric and Manufacturing Company then absorbed the Electric Company by stock purchase, and continued business with the personnel and organization of the Electric Company. In 1889 the capital was increased to $5,000,000, and in 1890 to $10,000,000.

In 1891, the company was reorganized under a plan by which the assenting stockholders surrendered 40 per cent of the holdings in common stock. $1,000,000 of such surrendered stock was converted into 7 per cent cumulative preferred stock and added to $3,000,000 preferred stock, then in the treasury. Stock surrendered at this time and the treasury common stock was called "assenting" stock, and that not surrendered was called "non-assenting" stock. These terms continued in use until 1911, when the company, having acquired and retired all of the non-assenting stock, exchanged new common-stock certificates for the existing assenting stock.

In 1907, the company passed into receivership, and readjusted its affairs under a plan by which $6,312,000 of common stock was sold at par and $3,578,754 of convertible bonds were issued to creditors.

In 1915, control of the Westinghouse Machine Company was secured by exchanging one share of Electric stock for three shares of Machine stock, and in 1917 the Machine Company was merged into the Electric Company.

Dividends Per Cent

	Capital Stock	Preferred	Common	Sales	Surplus
1900	$11,000,000	7	5¾	$11,963,000	$4,693,000
1905	28,000,000	10	10		
1910	41,000,000	10½	0	29,249,000	5,669,000
1915	41,000,000	7	4½	33,671,000	7,473,000
1920	75,000,000	8	8	136,052,000	43,436,000
1925	119,000,000	8	8	157,880,000	51,199,000

TABLE 1

MANUFACTURE OF ELECTRICAL MACHINERY, APPARATUS, AND SUPPLIES
SUMMARY OF U. S. CENSUS STATISTICS

		1923	1919	1914
Number of establishments(²)		1,671	1,404	1,030
Persons engaged		309,113	271,912	144,712
Proprietors and firm members		588	473	368
Salaried employees and officers		73,633	59,065	26,266
Wage earners (average number)		234,892	212,374	118,078
Primary horsepower		480,268	438,082	226,320
Capital	($ — Thousands)	(¹)	857,855	355,725
Salaries and wages	($ — Thousands)	443,921	336,369	109,097
Salaries	($ — Thousands)	138,466	98,180	35,291
Wages	($ — Thousands)	305,455	238,189	73,806
Cost of materials	($ — Thousands)	548,627	425,098	154,728
Value of products	($ — Thousands)	1,293,002	997,968	335,170
Value added by mfg.	($ — Thousands)	744,375	572,870	180,442
Products as above(²)	($ — Thousands)	1,293,002	997,968	335,170
Other electrical prod. (³)	($ — Thousands)	82,465	65,558	24,262
Total prod. (⁴)	($ — Thousands)	1,375,467	1,063,526	359,432
Electrical prod. (⁵)	($ — Thousands)	1,315,593	986,952	341,481
Deduct:				
Vacuum tubes, etc.	($ — Thousands)	10,673	2,984	(⁶)
Telegraph app.	($ — Thousands)	2,086	2,649	(⁸) 202
Radio app.	($ — Thousands)	44,176	8,075	792
Telephone app.	($ — Thousands)	90,858	46,214	22,816
Total	($ — Thousands)	147,793	59,922	(⁹) 23,810
Net products(⁷)	($ — Thousands)	1,167,800	927,030	(⁹) 317,671

(1) Not available.

(2) Primarily engaged in the manufacture of machinery, apparatus, and supplies for employment directly in the generation, storage, transmission, or utilization of electrical energy.

(3) Electrical products of industries other than those referred to in footnote 2. (Subsidiary products.)

(4) This total includes non-electrical products of the establishments referred to in footnote 2.

(5) This refers to electrical products only but includes vacuum tubes, etc., telegraph, telephone, and radio apparatus.

(6) Not available separately. Must have been small.

(7) Electrical products exclusive of the deductions for radio, telephone, and telegraph.

(8) Not comparable on account of changes in classification.

(9) Approximate.

TABLE 1 (*Continued*)

MANUFACTURE OF ELECTRICAL MACHINERY, APPARATUS, AND SUPPLIES
SUMMARY OF U. S. CENSUS STATISTICS

		1909	1904	1899	1889	1879
Number of establishments(2)		1,009	784	581	189	76
Persons engaged		105,600	71,485	(1)	(1)	(1)
Proprietors and firm members		439	400	(1)	(1)	(1)
Salaried employees and officers		17,905	10,619	5,067	(1)	(1)
Wage earners (average number)		87,256	60,466	42,013	8,802	1,271
Primary horsepower		158,768	105,376	43,674	7,494	(1)
Capital	($ — Thousands)	267,844	174,066	83,660	18,997	1,510
Salaries and Wages	($ — Thousands)	69,574	42,932	25,211	5,366	683
Salaries	($ — Thousands)	20,193	11,091	4,632	(1)	(1)
Wages	($ — Thousands)	49,381	31,841	20,579	(1)	(1)
Cost of materials	($ — Thousands)	108,566	66,837	49,458	8,820	1,116
Value of products	($ — Thousands)	221,308	140,809	92,434	19,115	2,655
Value added by mfg.	($ — Thousands)	112,742	73,972	42,976	10,295	1,539
Products as above(2)	($ — Thousands)					
Other electrical prod.(3)	($ — Thousands)					
Total prod.(4)	($ — Thousands)					
Electrical prod.(5)	($ — Thousands)					

(1) Not available.
(2) Primarily engaged in the manufacture of machinery, apparatus, and supplies for employment directly in the generation, storage, transmission, or utilization of electrical energy.
(3) Electrical products of industries other than those referred to in footnote 2. (Subsidiary products.)
(4) This total includes non-electrical products of the establishments referred to in footnote 2.
(5) This refers to electrical products only but includes vacuum tubes, etc., telegraph, telephone, and radio apparatus.

TABLE 2

FOREIGN TRADE EXPORTS

YEAR[1]	ELECTRICAL MACHINERY	ELECTRICAL MACHINERY AND APPLIANCES TOTAL	ELECTRICAL EXPORTS LESS TELEPHONE, TELEGRAPH, ETC., EQUIP.[2]	
	$	$	$	
1898	2,052,564			
1899	2,736,110			
1900	4,340,992			
1901	5,812,715			
1902	5,379,746			
1903	5,779,459			
1904	5,645,809	10,507,013		
1905	7,290,932	11,253,904		
1906	7,869,137	14,800,237		
1907	9,005,766	17,268,406		
1908	8,495,219	15,249,436		
1909	6,449,526	12,524,391		
1910	6,048,263	14,742,395		
1911	8,024,628	18,727,455		
1912	8,444,863	20,169,362	19,126,809	
1913		26,772,816	25,186,165	
1914		25,060,844	23,371,301	
1915		19,771,757	18,546,125	
1916		30,256,778	28,778,896	
1917		51,903,823	49,410,930	
1918		54,546,961	51,685,735	
1919		79,718,712	75,104,427	
1920		93,184,064	88,571,279	
1921		88,930,908	83,121,094	
1922		53,146,630	44,749,010	
1923		59,926,729	53,822,956	
1924		69,827,734	58,185,667	
1925		73,789,618	58,694,725	
1926		84,225,544	68,487,242	

ELECTRICAL IMPORTS

		$		
1923		2,265,946		
1924		2,768,276		
1925		2,432,735		
1926		2,520,130		

(1) Fiscal years, 1898 to 1918, thereafter calendar years.

(2) From 1912 to 1921, incl. the deductions are telegraph apparatus and telephones; from 1922 on, all signal and communication devices.

TABLE 3

CENTRAL ELECTRIC LIGHT AND POWER STATIONS — U. S.
SUMMARY OF U. S. CENSUS STATISTICS

		1922	1917
Number of establishments		6,355	6,542
Commercial		3,774	4,224
Municipal		2,581	2,318
Plant and equipment	($ — Thousands)	4,465,016	3,060,392
Commercial	do	4,229,356	2,933,017
Municipal	do	235,660	127,375
Total revenues	($ — Thousands)	1,072,120	526,894
Commercial	do	986,684	486,634
Municipal	do	85,436	40,260
Total expenses	($ — Thousands)	859,625	426,568
Commercial	do	792,496	395,127
Municipal	do	67,129	31,441
Total employees		150,762	105,541
Commercial		136,105	94,679
Municipal		14,657	10,862
Prime movers:			
Number		13,262	13,795
Total horsepower		20,296,235	12,936,755
Generators:			
Number		12,701	13,428
Kilowatt capacity		14,313,438	8,994,407
Output, Kilowatt hours:			
Generated	(Thousands)	40,291,536	25,438,303
Purchased	do	9,982,676	5,605,746
Number of customers		12,709,868	7,178,703
Number of customers' meters		12,590,306	7,102,569

TABLE 3 (*Continued*)

CENTRAL ELECTRIC LIGHT AND POWER STATIONS — U. S.
SUMMARY OF U. S. CENSUS STATISTICS

		1912	1907	1902
Number of establishments		5,221	4,714	3,620
Commercial		3,659	3,462	2,805
Municipal		1,562	1,252	815
Plant and equipment	($ — Thousands)	2,175,678	1,096,914	504,740
Commercial	do	2,098,613	1,054,035	482,720
Municipal	do	77,065	42,879	22,020
Total revenues	($ — Thousands)	302,273	175,642	85,701
Commercial	do	279,054	161,630	78,736
Municipal	do	23,219	14,012	6,965
Total expenses	($ — Thousands)	234,577	134,197	68,081
Commercial	do	217,660	123,880	62,835
Municipal	do	16,917	10,317	5,246
Total employees		79,335	47,632	30,326
Commercial		71,395	42,066	26,909
Municipal		7,940	5,566	3,417
Prime movers:				
Number		11,902	10,998	7,850
Total horsepower		7,530,044	4,098,188	1,845,048
Generators:				
Number		12,610	12,173	12,484
Kilowatt capacity		5,165,439	2,709,225	1,212,235
Output, Kilowatt hours:				
Generated	(Thousands)	11,569,110	5,862,277	2,507,051
Purchased	do	2,613,503	(1)	(1)
Number of customers		3,837,518	1,946,979	(1)
Number of customers' meters		3,617,189	1,683,917	(1)

(1) Not reported.

TABLE 4

Central Electric Light and Power Stations in New York State
Growth since the Beginning of the Industry

Year	Number of Stations Installed Each Year	Number of Stations in Operation	Value of Plant and Equipment	Total Revenues	Total Expenses	Prime Movers Horse-power
			($ — Thousands)	($ — Thousands)	($ — Thousands)	
1881	7					
1882	2					
1883	3					
1884	3					
1885	13					
1886	14					
1887	33					
1888	31					
1889	25					
1890	(To May 31) 8	139	31,184	4,175	3,078	59,512
1902		256	112,999	16,855	14,706	323,413
1907		314	252,732	34,859	25,962	722,653
1912		321	350,527	57,219	44,298	1,157,809
1917		332	418,138	84,717	67,233	1,811,066
1922		291	608,162	158,786	125,127	2,684,130

CHAPTER IX

THE IRON AND STEEL INDUSTRY

By Marshall T. Jones[1]

Introduction. Looking around one, at the marvels of the present age, with its radio, aëroplanes, television, and what not, it seems incredible that these various wonders are dependent upon one key industry, that of the manufacture of steel. Without this basis fundamental process, without the furnishing of the mighty machines and their tools responsible for the forming of the mightiest gun or the most delicate mechanism, all this would be impossible of accomplishment.

Our daily life is made easier through the use of this common metal, iron, from the time our alarm clock, made mostly of steel, arouses us from our steel-framed bed until we return thereto in the evening. We are practically never out of sight, during our waking hours, of some form of iron or steel, whether working or playing. Even in the wilderness, the axe, hunting knife, gun, strap buckle, shoe hobnail, and so forth and on, all are products of the lowly iron ore. Almost any other industry could be dispensed with, without causing the acute distress that a cessation of the steel industry would inflict, for to begin with, the automotive field, the hospital operating room, means of communication, all would be crippled if deprived of steel. And yet the tremendous activity that marks a steel plant would be non-existent but for one outstanding invention, the Bessemer convertor.

In considering the place held by this gigantic industry in the industrial realm of the United States, taken as a whole with all the many ramifications, it is undoubtedly the leader. As regards its position in the world at large, in 1926 out of a total of approximately ninety million gross tons of steel ingots produced, our country contributed forty-nine million tons, roughly 55 per cent, or

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more than one half; and all but two million tons were consumed at home, made possible by the tremendous industrial growth in the past few years and the amazing period of prosperity now holding sway, wherein building activities have never been so pronounced, or automobiles so numerous, or many, many other fields so active as at present, making possible the absorption of this tremendous amount of steel.

And yet the productive capacity of 87.5 per cent of the entire country's output is vested in only twenty companies, the single largest one being the U. S. Steel Corporation, capable of producing 41 per cent of the total in the United States. Then the Bethlehem Steel Company follows with 13.5 per cent, with others, lesser ones, none of which produce above 6 per cent.

The history of the steel industry in this country may well be split up into two periods, Pre-Corporation and Post-Corporation, referring to the time in 1901 when the U. S. Steel Corporation was formed. The first stage was one of invention and adjustment, the perfecting of processes and formation of a number of companies eagerly engaged in trying to undersell each other. At one stroke, with the combining of approximately two thirds of the country's capacity into one amalgamation, this situation was relieved. From then on, its growth has been steady and natural, with minor adjustments and consolidations from time to time, but through it all the Steel Corporation has been the leader, encouraging competition rather than stifling it, so that whereas at its inception its mills held two thirds of the country's capacity, today this portion has fallen to 41 per cent.

Throughout this article on the industry, reference is frequently made to the U. S. Steel Corporation, because of the fact that the two are inseparable and that the growth of the industry to its present position of sound stability has been accomplished through the leadership of that Corporation with its able management, which has built up present ethics and has acted as a curb on price fluctuation. So that while there is no intention at all of belittling the efforts of the splendid group of men which has guided the other companies, space here does not permit of more than mere mention.

Growth of Pig-Iron Production in the United States. Although pig iron was made by using coke for fuel in Great Britain as early as 1735, and by 1796 charcoal as a fuel in the blast furnace had

been abandoned, it took over one hundred years for coke to be successfully handled in the furnaces of the United States. The earliest experiment, in so far as can be ascertained, in this country in making pig took place in 1819, in Pennsylvania, but for the next twenty years it still continued in the experimental stage, until in 1839 three furnaces at Lonaconing, in western Maryland, were turning out about 70 tons per week of good-quality foundry iron.

Various reasons have been advanced for the delay of a century in adopting coke as a fuel in the United States, the principal ones being lack of transportation facilities, inability to make good coke from the coal deposits then available, the presence of plentiful supplies of timber for charcoal, and finally charcoal iron was then held in great esteem.

Even as late as 1849, there were no furnaces using coke in Pennsylvania, but in 1856 there were 21 such furnaces, with 3 more in Maryland, and production reached 44,481 gross tons in that year. Nine years later the amount of coke used had reached the 100,000 ton mark, increasing in 1880 to 2,128,255 net tons, and to about 10,000,000 net tons ten years later.

The outline of the production of pig iron in the United States may be sketched with figures from the Census returns beginning with 1810, which placed the total output at 53,908 tons, and at 20,000 and 165,000 tons in 1820 and 1830, respectively. For 1840 the output of this product was placed at 286,903 tons, and ten years later at 564,755 tons.

The organization of the American Iron and Steel Association (now " Institute ") at Philadelphia on March 6, 1855, marked the beginning of the regular annual publication of pig-iron production figures with which we are all so familiar. By 1854, production had reached the stupendous figure of 736,218 net tons, of which amount about one half was charcoal pig and the balance made by using raw anthracite coal as fuel. Gradually, however, the production of coke pig crept up to that of charcoal, passing it in 1869, and in 1875 passing the tonnage mark of that made with raw anthracite, and from then on steadily forging ahead until, in 1890, out of a total of 10,307,028 net tons of pig produced in the United States, that made with coke amounted to 7,154,725 tons, with the balance mostly made up of pig manufactured with raw anthracite as a fuel. This same year, 1890, marked the passing of the United States into first place among the world powers as a producer of

pig iron, a place which had hitherto been held by Great Britain, but has since been held without interruption by the United States.

Growth of Steel Production in the United States. Steel making, in the meantime, was also going through the various development stages. Mention is made in 1655, by John Tucker, of steel being made at Southold, Long Island, but it was not until 1750 that definite progress in this art was reported, which progress took place in Massachusetts as well as in Connecticut, Pennsylvania, and New Jersey. By 1791, it is stated that domestic production supplied one half of the home demand, and in 1810, 917 tons of steel were turned out, Pittsburgh having the distinction of being the site of the first furnace built in this country, which, erected in 1813, was owned by Tuper and McKowan. At that time, the only process used was that known as "cementation," making what was termed "blister" steel. It might be of interest here to make note of some cost figures which are available dating back to 1772, when the cost of making a ton of steel was given as £56, and sold at that figure by Aaron Eliot, at Killingworth, Connecticut, to New York City merchants who furnished the iron, and then resold by them at from £75 to £80.

In 1831, the best steel was imported, mostly from England, which was made from Swedish ore. At that time blister steel of the best quality was imported and cast steel made from it. Up to about 1860, progress in steel making was very slow. One successful attempt, however, stands out, for in 1832 Garrard Brothers attempted to produce crucible steel at the Cincinnati Steel Works. Spring steel at that time was selling for from 10 to 15 cents per pound, and the best cast steel from 18 to 25 cents, but the panic of 1837 put an end to this attempt. This panic, it is stated, was brought about by a reduction in the tariff, resulting in an increase of cheap imports, which naturally killed off the infant industry. This took place during President Jackson's first term.

The Adirondack Iron and Steel Company was formed in 1849, to make crucible steel. It was leased in 1853 for a period of ten years, then sold, and finally was dismantled in 1885. This was the first steel company to last that number of years. The steel made was used to make picks, mattocks, hoes, files, saws, axes, springs, and a variety of other implements. German steel that was imported was at that time utilized in the manufacture of springs and plow shares.

Then came a revolutionary invention in 1853, that of making plumbago crucibles, by Joseph Dixon, whose company is still in existence. Ten years later, in 1863, three firms were well established making crucible cast steel. Two years prior to that, the Morrill tariff was enacted, which afforded protection to the industry, as up to that time it had been stifled, due to the cheap importations from the Continent. The production of crucible steel had amounted to 89,762 net tons by 1881.

The advent of the commercialized Bessemer convertor marked the greatest milestone to be passed, only seconded by the adoption of the open-hearth furnace. But for the birth of this quick method of making steel by blowing air through molten iron, the development of the United States would have been greatly retarded. For without steel rails, the railroads could not have been pushed to completion with such rapidity, to open up otherwise inaccessible territory. But more of these developments later.

Then the greater discovery took place, which supplanted this crucible product, as in 1855 and 1856 patents were granted in England to Sir Henry Bessemer, and the greatest stride in the industry up to that time was taken in the adoption of the Bessemer convertor into the steel family. But upon application of Bessemer to take out patents in this country, he was confronted by William Kelly, whose claim to priority was upheld by the Commissioner of Patents. During 1857 and 1858 experiments were carried on by Kelly at the Cambria Iron Works at Johnstown, Pennsylvania. Then came the use of the basic convertor lining, patents being granted in 1866 to Jacob Reese, and the Bessemer Steel Company, Ltd. finally acquired in 1888 the ownership of all the patents for the United States. In the meantime the Kelly Pneumatic Process Company was organized, the Kelly patent being taken over, as well as the Mushet (British) patent for the use of spiegeleisen as a recarburizing agent, with the result that in September, 1864, the first Bessemer steel to be turned out in the United States was made at Wyandotte, Michigan. But because of the fact that a part of the machinery used infringed upon the Bessemer patents, and that Mushet's patented process using spiegeleisen was essential to the holders of the Bessemer patents, the combination was finally effected, with the resultant Bessemer Steel Company, Ltd. holding all rights. This company was succeeded in 1890 by the Steel Patents Company.

Iron rails were being manufactured in the United States prior to the advent of the Bessemer convertor, and one of these rolling mills, at North Chicago, had the distinction in 1865 of rolling the first steel rails in this country from steel ingots made at the Wyandotte plant mentioned above. These first six rails were laid in the track of one of the railroads running out of Chicago and were still in service ten years later. From the period of 1865 to 1876 several of the present-day well-known steel companies had their inception. The Pennsylvania Steel Company, at Steelton, Pennsylvania, was organized in 1867, the Cleveland Rolling Mill Company, Cleveland, Ohio, in 1868, and three years later the Johnstown, Pennsylvania, plant of the Cambria Iron Company was established. That same year saw the birth of the Union Steel Company at Chicago, followed by the Joliet Steel Company at Joliet, Illinois, in two years. Also in 1873 the Bethlehem Iron Company, Bethlehem, Pennsylvania, made its appearance, and just fifty-two years ago the Edgar Thompson Works of Carnegie Brothers and Company, Ltd., at Bessemer, Pennsylvania, was first put in operation. That same year, 1875, witnessed a new plant being erected at Scranton, Pennsylvania, for the Lackawanna Iron and Coal Company. The largest convertor then in use had a capacity of 7 tons, and they seem to have been built in pairs. For some time difficulty was experienced in obtaining a sufficient supply of suitable domestic-made pig iron, so that quantities were imported for the purpose of making Bessemer steel, but that was soon remedied. The American Iron and Steel Association tabulated annually the production of Bessemer steel in the United States, starting with 1867, when 3000 net tons were manufactured, which production had grown to 375,517 tons in 1875, to 1,203,173 tons five years later, and to 4,131,535 tons by 1890. In the same first-mentioned year, American plants rolled 2550 net tons of Bessemer rails, which had increased to 290,863 tons in 1875, to 954,460 tons in 1880, and to 2,091,978 tons by 1890. It is interesting to note that during the year 1880 the production of Bessemer ingots in the United States amounted to 1,074,262 gross tons, while in England the production was 1,044,382 tons, indicating that the United States for the first time surpassed that country in tonnage, and the year before the tonnage of rails turned out in America exceeded that turned out by the British mills, the figures being respectively 610,682 and 520,231 tons.

Since that time the United States has always held the lead over all other countries.

At the same time that patents were being granted in England covering the Bessemer process, the first patent was allowed there to Frederick Siemens on the open-hearth method of steel manufacture, and he subsequently combined his invention with those of two Martin brothers into what is today known as the Siemens-Martin furnace. Its first appearance in the United States took place in 1868, at the Trenton, New Jersey, Works of New Jersey Steel and Iron Company, but it was not until 1888 that basic open-hearth steel was really manufactured on a commercial basis, at which time the Homestead Works of Carnegie, Phipps and Company, Ltd., at Homestead, Pennsylvania, turned out the first of this product. The Steelton Works of the Pennsylvania Steel Company, previously mentioned, about this same time also turned to a combination of the Bessemer and open-hearth methods, and in 1890 the Henderson Steel and Manufacturing Company, at Birmingham, Alabama, experimented with the basic open hearth, followed by the Southern Iron Company at Chattanooga, Tennessee. In 1891, this last-named company successfully turned out basic Bessemer steel, the first to be produced in the South. By 1890, there were 62 open-hearth steel works in the United States. Production, as compiled by the American Iron and Steel Association, started with 1500 net tons in 1870, increasing to 112,953 tons in 1880, and to 574,820 tons in 1890. In comparison with these figures, the production in Great Britain in 1880 was 251,000 gross tons, and in 1890 it was 1,564,200 tons.

Mention has been made previously of the fact that in 1865 the first Bessemer steel rail to be made in the United States was rolled. It had only been twenty-two years prior to that date that the first heavy iron rails had been rolled in America, which event took place in Maryland at the Mount Savage Rolling Mill. The weight of this rail was 42 pounds per yard. During the previous ten to fifteen years, such rails as had been used in this country had been imported from England. Production of iron rails in 1849, the year first recorded, was 24,318 net tons, reaching the high figure of 905,930 tons in 1872, and then declining to 15,548 tons in 1890. The year 1883 saw iron rails being superseded by steel ones. By 1890, there were 208,303 miles of railroad track in the United states. Manufacture of iron rails ceased after 1902, except for a few hundred tons.

The building of iron steamships was developing, and the first ships of any size were completed in 1871 and the two years following by William Cramp and Sons at Philadelphia. These four vessels had a tonnage of 3100 tons each. And in 1874, two steamers were built for the Pacific Mail Steamship Company, for the Pacific Trade, which concern finally has been dissolved in 1925. Since 1883, practically all the vessels built have been made of steel.

Cut nails were an American invention, and were first manufactured about 1775 in Rhode Island. During the ten years following 1825, there was a great expansion in the cut-nail industry, many plants springing up. Then in 1851 or 1852, the first wire nails were made in the United States, in New York, by William Hassall. It was not until twenty-two years later that the nail made from Bessemer steel wire actually became a serious competitor of the cut nail, but from then on its production was very much increased from year to year. By 1890, there were produced 5,640,946 kegs, of 100 pounds each, of cut nails, and 3,135,911 kegs of wire nails, but by 1894 there were about twice the number of wire nails produced as there were cut ones, and so on up, until in 1925 there were about twenty times.

Although statistics are available showing importation of tinplate as far back as 1871, amounting to 82,969 gross tons, and although domestic manufacture was attempted in 1873, it was not until 1891 that there was a serious start made, in which year 6092 gross tons were turned out. Within two years this had increased ninefold, and by 1895 reached a total of 113,666 tons. Up to 1912, the imports steadily fell off, while domestic production grew to 1,657,795 gross tons in 1925. 1897 was the first year that home production surpassed imports. The Tariff Act of 1890, affording double the previous protection, was responsible for the growth of the American industry in this line.

There were several events of importance in the growth of this infant iron and steel industry, notable of mention being the introduction of the hot-blast for the blast furnace in 1840, by David Thomas at Catasauqua, Pennsylvania. Then during the period from 1850 to 1860, rolling-mill machinery was made much more efficient than before, the 3-high roll train was introduced, rolls to turn out structural beams were first used by Cooper, Hewitt, and Company, at Trenton, New Jersey, and by 1860, the universal

mill was adopted. So that by 1890, the United States turned out 35.2 per cent of the world's production of steel. Another important development took place when in 1891 both the Bethlehem Iron Company, and Carnegie, Phipps and Company were persuaded to build plants to manufacture armor plate, to so equip the American naval vessels that were then building. And by 1895, the United States was independent of the rest of the world as regards the iron and steel products, as the two products, tin plate and armor plate, theretofore imported, had been successfully produced.

In the present days of severe Continental competition, it is interesting to read that in 1881, forty-six years ago, that whereas in Pittsburgh the wage paid for puddling iron was $5.50 per ton, the similar figure for British labor was the equivalent of about $1.75 per ton, and less than that on the Continent, which is about the same ratio prevailing today. Then, too, the coke and the ore may be separated in the United States by about 1000 miles whereas 100 miles would represent the longest distance apart of these two commodities in England. On the average, iron ore is transported about 400 miles in the United States, and coke about 200.

Consolidation Movements. By 1898, the period of adjustment in the industry had been completed, processes had become more or less stabilized, and the field was dominated by many companies, all competing with each other rather severely, with accompanying pools and price agreements. A considerable number of consolidations took place, small companies combining to the extent sometimes of a new capitalization of $100,000,000. The ruling motive appeared to be removal of competition. There resulted the formation of three outstanding concerns: the Federal Steel Company, the Carnegie Steel Company, and the National Steel Company, with, of course, a host of smaller ones. These came into being during the years 1898 to 1900, and controlled the larger portion of production of crude and semi-finished steel.

The American Steel and Wire Company, American Tin Plate Company, The American Steel Hoop Company, American Sheet Steel Company, the National Tube Company, and the American Bridge Company formed the backbone of the producers of finished steel products. Both groups were dependent upon each other, as neither was self-contained, as regards the complete operations.

So the next thought that occurred to many of these concerns at about the same time was as to how they could become self-sustaining, that is, to link up ore and coal mines, blast furnaces, steel works, rolling mills, and finished manufacturing. The first-named of the finishing companies given above, the American Steel and Wire Company, in 1900 planned to produce its own steel, which the National Tube Company also planned to do. Previously those two had purchased their billets and sheet bars from the producing companies. Seeing their main customers thus slipping away, the ingot-producing companies therefore turned to the manufacture of finished articles of their own product.

And then came the scramble to secure the control of ore and coking coal, so that by the beginning of the present century, the Lake ore mines were practically held by less than a dozen concerns; similarly the coal mines. So the situation resulted in having a number of giant companies striving to cut each other's throats, with corresponding ruinous competition and losses.

At this particular crisis, the man who until his recent death held the unique position of greatest industrial leader of the present quarter century, Judge Elbert H. Gary, was the particular lawyer selected by J. Pierpont Morgan to handle the legal side of the formation of the United States Steel Corporation. With dramatic and incredible speed, the amalgamation was accomplished, incorporation taking place under the New Jersey laws, as of date of February 25, 1901. The total capitalization, including bonds, was approximately $1,402,000,000. The original companies, thus consolidated, were twelve in number, and included in addition to the three producers of crude steel and the six companies manufacturing the finished products, all mentioned above, the Bessemer Steel Company, the Shelby Steel Tube Company, and the Lake Superior Consolidated Iron Mines. The next year the Union Steel Company was acquired, and two years later the Clairton Steel Company was absorbed, and, in 1907, the Tennessee Coal, Iron, and Railroad Company was added.

At the time of its organization, the Steel Corporation controlled about two thirds of the crude-steel production, and from one half to four fifths of the production of the finished rolled-steel products. It became an entirely self-contained unit, controlling all the raw materials, ore transports, right through to the finished article. And at the helm of this, the greatest industrial enterprise of the

world, Judge Gary steered a safe course through reefs of many kinds, including such as the suit instigated against the Corporation by the United States Government, under the authority provided by the Sherman Anti-Trust Act, through which the Corporation sailed to a safe harbor largely on account of the splendid ideals its leader promulgated throughout his entire term of office. Another victory scored was the defeat of the labor leaders when attempting to force the union-shop principle upon the steel mills. But more of this later on.

Whereas at the time of its formation the United States Steel Corporation controlled about 60 per cent of the country's steel production, this had, by 1910, fallen to about 50 per cent, and at present writing is about 41 per cent. Its holdings of Lake ore amount to roughly 75 per cent of the available supplies of that area.

The independent companies, those that remained outside the Corporation, must not be overlooked, as after all, while not individually approaching anything like the magnitude of that organization, collectively they represented 40 per cent of the country's capacity in 1901, and have grown to about 59 per cent at the present time. The list contains such well-known names as Bethlehem Steel Company, Jones and Laughlin Steel Company, Pennsylvania Steel Company, Cambria Steel Company, Lackawanna Steel Company (now a part of Bethlehem Steel Co.), Republic Steel Company, The Colorado Fuel and Iron Company, Youngstown Sheet and Tube Co., Wheeling Steel Corp., etc.

The Federal Steel Company, incorporated in 1898, was a combination of the Illinois Steel Company, Lorain Steel Company, Minnesota Iron Company, and the Elgin, Joliet, and Eastern Railway, and represented about 15 per cent of the steel-ingot production of the United States. The National Steel Company, formed the following year, held about 12 per cent of the ingot production, and the Carnegie Company of New Jersey, formed of the Carnegie Steel Company, Ltd., and the H. C. Frick Coke Company, held fully 18 per cent of the ingot manufacture. The American Tin Plate Company held almost a complete monopoly of that product by combining in 1898 very nearly all the plants making tin plate. Then in that same year the American Steel and Wire Company combined all wire plants into one company. The National Tube Company acquired the bulk of the tube mills

in 1899, and likewise the American Steel Hoop Company gained control of hoop production. The American Sheet Steel Company, now combined with the American Tin Plate Company, into the American Sheet and Tin Plate Company, was promulgated in 1900, controlling sheet-steel production, which same year heralded the formation of the American Bridge Company for making fabricated steel, and the Shelby Steel Tube Company for seamless tubing. Other integral units formed at the same time were such concerns as the Republic Iron and Steel Company, in 1899, combining makers of rolled products in the Middle West and some Southern plants; the Sloss-Sheffield Steel and Iron Company, which consolidated various furnaces in the South; the Pennsylvania Steel Company, in Eastern Pennsylvania and Maryland, greatly extended its operation in 1901; the Cambria Steel Company, reorganized in 1898, also enlarged its activities; the Lackawanna Steel Company did likewise in 1902, and the Jones and Laughlin Company greatly expanded its Pittsburgh plants.

Thus during the comparatively short period of four years, from 1898 to 1902, these consolidations that took place represented capital stock issues of approximately $1,600,000,000, which were apparently readily absorbed by the investing public.

The detailed story of the formation of the U. S. Steel Corporation is one of the most interesting of studies ever written on industrial development, as it brought under one roof interests sponsored by Morgan, Moore, Carnegie, and Rockefeller, names to conjure with. This present article does not permit of more than reference to the general outline.

In 1890 there were scarcely any consolidations of the modern type in the steel industry. During the eight years following, minor consolidations were taking place, preparing the way for the major amalgamations accomplished in the three years following 1898. Also at this time there was a noticeable reaching out after raw materials, namely, ore and coking coal, as the larger companies then operating seemed to sense the impending conflict, wherein the Company which possessed its own ore resources, railroad, and lake vessels to transport this ore and coking coal supplies would be in the best position to hold on in the event of a price war due to competition. Thus did the larger companies round out their holdings to the situation at present obtaining.

One feature that amazed the public and those who had predicted

ruin for the Steel Corporation was the fact that during the first nine months of its existence, profits after dividends amounted to \$44,000,000. The splendid feature of this accomplishment was that steel prices had remained at the same level as before although the orders booked for future delivery by the Corporation might well have justified an increase. But throughout the term of his leadership, Judge Gary strictly adhered to the principle that prices were sufficient which yielded a reasonable return on the investment, and this one factor has made for stabilization in this basic industry. And here again Judge Gary's sense of fairness overruled objections, by having the annual report made public immediately after it had been presented to the Board of Directors, a practice which has now become customary.

At this time that well-known steel official, Charles M. Schwab, who had formerly been President of the Carnegie Steel Company, had been made President of the Corporation, which position he held until August 4, 1903, at which time he organized the Bethlehem Steel Company into what has now become the second largest steel combination in the United States, which has at present an ingot capacity of roughly 15 per cent of the total capacity of the country, by absorbing in 1916 the Pennsylvania Steel Co., and in 1922 and 1923 the Lackawanna and Cambria Companies.

Another feature which has been consistently followed by the Steel Corporation has to deal with foreign trade. Almost immediately upon the formation of the Corporation, a selling organization was set up to represent in the export field all of the constituent companies of that body. This organization was known as the U. S. Steel Products Export Company, later on the "Export" being dropped. James A. Farrell, now President of the Corporation, was placed in charge of this infant, and he proceeded to organize his company along commodity and regional lines, having men from each member company to handle orders received for their respective commodities. Offices in foreign lands were established, managed by men from the Corporation's own staff, and foreign business was thus gradually developed, until today the United States Steel Products Company ships about 60 per cent of the total American steel going abroad, their activity in this trade being indicative of their intention to sell their products abroad as long as they may profitably do so.

Only one other company has ever attempted to sell steel outside

of the United States on anything like the same scale, and for that purpose the Consolidated Steel Corporation was formed under the Webb-Pomerene Act, which company represented for export, concerns not otherwise affiliated and even competing with each other in some lines.

This company, however, was dissolved in 1923, as the Bethlehem Steel Company, the largest individual member, absorbed several of the other companies in the group, which combination represented over one half of the production in the Consolidated Steel Company, which was composed of eleven companies in all. Foreign offices were opened and a fair share of the foreign trade obtained. One respect, however, in which this company differed from the U. S. Steel Products Co. was the fact that the latter had a call upon a certain fixed percentage of the Steel Corporation's tonnage for export, regardless of domestic orders. Also a fleet of some 35 vessels, each of 10,000 tons deadweight capacity, was built at the Corporation's own shipyard, that of the Federal Shipbuilding Company, which were available to carry the company's steel anywhere in the world. Thus obligated deliveries could be filled regardless of outside shipping conditions. A very definite policy had been laid down by James A. Farrell, and still carried out by his successor, and to this day he keeps close tabs on the export company. The Consolidated Steel Corporation, however, had a great deal to contend with in allocating orders received from abroad to the different mills, as, of course, there are desirable orders and undesirable ones.

Several of the other large steel companies, and many of the smaller ones, maintain export divisions, but do not attempt to set up their own foreign offices, dealing sometimes through foreign representatives or direct with their various clients, or through commission houses.

Labor Problems. Labor conditions in the steel industry have on the whole been satisfactory and free from controversy, with a few exceptions. The Steel Corporation has always assumed the lead by doing all in its power to make the men contented, to preserve their health, and afford means of recreation. In 1901, on July 1, the head of the Amalgamated Association of Iron, Steel, and Tin Workers announced that a strike would take place in some of the Corporation's plants unless certain conditions were met, but this fell flat, and by August the order was rescinded. This

association listed about 14,000 members, a very small percentage out of a total of 434,000 workers in the industry at that time, 168,000 of these being employees of the Corporation. The terrific struggle that took place in 1892, referred to as the "Homestead" strike, will long be remembered. That strike affected only that one plant, but was the first serious clash between labor and capital in the steel industry.

But in 1903 a plan was instituted whereby employees of the U. S. Steel Corporation could purchase the stock of the Corporation, on a three-year payment basis. This was the first attempt of its kind among the larger industrial concerns. From 1903 to 1908 inclusive, preferred stock was offered. From 1909 to 1914 inclusive, subscriptions to both preferred and common stock were taken, except in 1910 when only preferred was offered. In 1915 no offer was made, but from 1916 to date the plan has provided for subscriptions to common stock only. Safety campaigns were inaugurated, bonus systems started, and the care of sick and injured employees given attention; in fact, efforts were made to aid the employees financially, physically, and intellectually. And the announced policy of the leaders was to the effect that where there were already union affiliations, these should not be disturbed, but that the open-shop policy should operate in all mills of the Corporation, which to this day holds true. The other steel companies follow suit, and at present the steel industry is practically the only large one not dominated by the labor union.

Another very determined effort was made by the labor leaders to force unionization upon the steel industry in 1919. Judge Gary flatly refused to treat with the leaders, stating that he did not believe they represented the workers in the Corporation's mills. This so-called strike lasted from September 22, 1919, until January, 1920, but did not have any appreciable effect upon the industry except in isolated cases. And upon investigation, it was apparent that the adherents to the movement included less than half of the unskilled foreign workers. The Corporation being the largest company, what success or failure the strike had would determine the status of the rest of the mills in the country. But during the eighteen years of its existence prior to the strike, a matter of about eighty million dollars had been expended voluntarily by the Corporation in providing schools, hospitals, playgrounds, etc., for its employees. The other companies have

done likewise, to a greater or lesser degree, according to their ability to make such expenditures.

American Export Trade in Steel. The first recorded exportation of iron products from the United States is given as having occurred in 1717, when 2 tons of iron bars were sent from one of the West Indies to England, which bars had been made in the United States. Pig iron was first exported during 1728–29. Until 1840 our annual exports never exceeded one million dollars in value, but by 1865 had reached the ten million dollar mark. Up to 1881 they averaged about fifteen million dollars, while imports totaled eighty million dollars in 1880, the highest figure reached. By 1890, imports had dropped to forty-four million dollars, while exports had increased to twenty-seven million dollars' worth.

With respect to the other four leading producers of iron and steel, namely, United Kingdom, Germany, Belgium, and France, the United States in 1898 assumed third place as to exports, the United Kingdom holding first by more than fourfold, with Germany just a little ahead in second place. The United Kingdom had for years held sway, for example, in 1886 exporting 3,388,494 gross tons of iron and steel products, compared with 498,632 tons from Germany, 458,739 tons from Belgium, 40,353 tons from France, and 21,095 from the United States. Germany's foreign shipments surpassed those of the United Kingdom in 1910 and continued to each year up to and including 1913. Then during the War and for the three years following the Armistice, the United States dominated the trade abroad, giving way, however, to the United Kingdom and Germany in 1922, and finally in 1925, the last year for which complete figures are available, dropping to fifth place. In so far as percentage is concerned, in 1925 the United States held 11.2 per cent of the world's trade, which corresponded to the situation in 1910, when the figure was 11.4 per cent. The portion had increased steadily from 1910 to 77.9 per cent in the last War year, 1918, and has dropped consistently.

Not counting those war years, the difficulty since 1922, during which year the other countries had more or less recovered from the effects of the conflict, has been in the matter of costs and prices. While prices remained high, due to demand exceeding supply, the United States could and did obtain a goodly share of the foreign business offering. But beginning with 1923, both Germany and Belgium forged ahead, due to their labor costs being but one

quarter of those obtaining here. This applied particularly to bars, shapes, and plates, the heavy tonnages, wherein both the United Kingdom and the United States were handicapped — the former in nearly the same position as the latter, with costs but slightly lower.

There are five items which form the backbone of our exports, and from the foregoing it will be deduced that our only competitor is Great Britain. These five articles are tinplate, galvanized and black steel sheets, rails, and welded pipe. These comprise about three quarters of our exports, and are all well-known American products in foreign lands.

But out of a grand total of 15,802,117 gross tons exported by these five leading countries in 1925, our share of 11.2 per cent amounted to only 1,762,572 tons, with the other four countries dividing the balance fairly evenly. Our position differs from that of the others, however, in that they must export to carry on operations, for without the outside markets their costs for steel products for their own markets would be prohibitive. For example, in 1925, the United Kingdom's exports amounted to 50 per cent of its ingot production, Germany's were 25 per cent, Belgium and Luxemburg combined shipped out 75 per cent of their combined production, and France's portion was 60 per cent of its output, whereas the United States only sent abroad about 4 per cent.

As has been previously stated, in 1890, the United States assumed first place as a world producer of pig iron, and from then on gradually increased production of both iron and steel, until, in 1913, 40 per cent of the world's output was manufactured here, and in 1926 was just over one half. The steel-ingot production of the world has increased 14,000,000 tons between these two dates, all of which advance the American manufacturers held, due mostly to increased capacity built during the War. Our tremendous prosperity, however, has permitted of the absorption of this 50 per cent greater tonnage, being utilized in automobiles, railroad rehabilitations, greatly enlarged building activities, etc.

Imports into the United States. Prior to the War, imports of iron and steel products into this country did not assume much significance, but starting in about 1923, steel from Europe began to appear on the American market. Pig iron from India was sold along the seaboard at prices several dollars below those quoted

by our furnaces. Then cast-iron pipe from France, in 1924, made its first appearance, and undersold the American product anywhere from one to ten dollars per ton. Later on, bars and shapes came into prominence, particularly from Belgium, and these factors have tended to upset the domestic market to a degree particularly noticeable in the case of cast-iron pipe.

In one sense, this operates for the good of the purchaser, but may well have a decidedly bad influence on industrial conditions. Fortunately for the industry as a whole, the markets most affected are those not very far inland, as railroad freight rates tend to equalize matters. Of course, the matter of service, reliability, etc. has a steadying effect, and latterly these importations have fallen off. The actual proportion of imports to domestic production is very, very small, about 2½ per cent, but the price menace in some cases is ever present, although it is, of course, impossible to shut the door completely, but as stabilization in Europe reaches more normal levels, these matters will straighten themselves out.

One important development that has taken an international place in the iron and steel industry was the formation on September 30, 1926, of the Continental Steel Entente, fostered by the industries of Germany, France, Belgium, Luxemburg, the Saar, Czechoslovakia, Austria, and Hungary. It is too soon to predict what influence this may have on the future status of our own industry, if any. But when one quarter of the steel-making capacity of the world is involved in a combination, it is to be assumed that some effect will be manifested. During 1926, these eight countries produced one third of the world's production of steel ingots, approximately 30,000,000 tons out of a total of 90,000,000. The United States produced in that year, roughly, 49,000,000 tons, or 55 per cent of the total.

The Entente provides for production quotas for its member countries, and a series of penalties and bonuses for over and under production, with the aim in view of stabilizing production to agree with consumption, and to more or less regulate prices. So far it has achieved a considerable degree of success, and is being watched very closely by the American industry, as the previous cut-throat competition indulged in by these countries had a far-reaching effect on our own foreign markets in other lands, and also upon importation into the United States itself. One immediate effect was to raise prices somewhat, and, of course, the nearer to our level

these prices come, the better our chance for obtaining business for our own mills.

Another striking feature which has tended to keep the industry in a healthy condition was the abolition, in 1923, of the method of quoting prices on the "Pittsburgh plus" basis. At present, prices are given as in the case of other commodities, at so much f.o.b. mill plus railroad freight to destination. The former method tended to penalize mills not situated in the Pittsburgh district, but the present method is quite fair to all concerned.

During the world war a certain fixed price was determined for steel, and rigidly adhered to, and all the vast resources of the industry were thrown without reserve into the struggle. Naturally, afterwards the tremendous increase in capacity brought about by wartime demands had to be carefully considered, but the country was able to absorb this increase in production because of the years during the war when steel for civilian purposes could not be had, created an unprecedented outcry for steel of all kinds. And then the wave of prosperity following the depression period of readjustment in 1920 and 1921 has made possible this stupendous growth in the industry.

In conclusion, it may be stated that the iron and steel industry in the United States was never on a more sound and stable basis than at present, and while consumption will undoubtedly not continue indefinitely at the present rate, the falling off will be gradual, if a decline is in the offing. A very high degree of perfection has been obtained by the furnaces and mills, and while minor improvements in methods and operations will continue to be made, the next radical change seriously to affect the industry, which cannot but be beneficial, will be the commercialization of a process of producing steel direct from the ore without the intermediate step of making pig iron. There are today several such processes in operation, utilizing the electric arc principle, but the scale of operation is too small to permit of its adoption in place of the open-hearth furnace as yet. But the time will come when this will be accomplished, and when that does happen, in all probability the price of steel can be further reduced.

Just a word in tribute to Judge Gary, who stated in an interview shortly before his death, that he had "put it up to his associates as to when his period of usefulness should be ended." At the age of 81 years he was still "in his prime," and it is with

the deepest regret that his splendid domination of the vast industry could not continue longer. However, the standards he promulgated will long be held as the "standards in business ethics," and the spirit that had as its motto "IT CAN BE DONE" will be the industry's guiding influence for many, many years to come.

CHAPTER X

THE LEAD MINING AND SMELTING INDUSTRY

By H. T. Warshow [1]

Lead is one of the irreducible elements in nature. In Latin it is called "plumbum," but its English name is derived from the Anglo-Saxon "leād," which bears a close resemblance to the Dutch "lood" and the Scandinavian "lod." Little is known about the original discovery of this metal, but it is generally considered to be one of the six "prehistoric" metals. It is referred to in the Old Testament,[2] and there is evidence of its use by the Egyptians as far back as the period 7000 to 5000 B.C. One of the oldest pieces of lead known to be in existence is that of a figure in the British Museum, which antedates 3800 B.C. Recent archeological investigations have disclosed leaden objects of even greater antiquity.

The famous Rio Tinto deposits in Spain, the upper portion of which carry silver-bearing lead ore, were worked by the Phœnicians as early as 2300 B.C. The Greeks worked the lead mines at Laurium in the fifth century B.C. The Romans worked the lead mines in Sardinia and in Southeastern Spain in the third century B.C., and also the mines in England during their occupation of that country. It is an interesting fact that some of the regions worked for lead-silver ores thousands of years ago, especially the region in Southeastern Spain, are still producing lead in important quantities.

The usefulness of lead to society, though always considerable, has increased immeasurably with the introduction and general adoption of machine processes. When combined with tin in

[1] Comptroller, National Lead Company.

[2] "Only the gold, and the silver, the brass, the iron, the tin, and the lead — everything that may abide the fire ye shall make it go through the fire and it shall be clean." (Numbers XXXI, 22–23.)

Babbitt metal, it finds its way into machinery of every description, as in the automobile, for instance. The large consumption of lead for paint pigments, storage batteries, ammunition, underground cables, and the many divisions of the building industry, is common knowledge. The part that it plays in petroleum refining and in the manufacture of such products as glass, rubber, enamel, and pottery, is, however, not so generally known, but is none the less important.[1]

Lead is a metal which is rarely found alone in nature. Most often it is contained in galena (lead sulfide) and other ores. In order to transform the ore into usable metal, it is necessary to put it through the processes of mining, milling, smelting and refining. The consideration of these steps, along with a discussion of prospecting, production and consumption, marketing, tariff policy, prices, labor problems and the financial organization of the industry, make up the ground to be covered by this chapter.

Production in the United States. The United States is the most important source for lead in the world. Its production amounts to about forty per cent of the world's total. Mexico is second with about thirteen per cent, Australia third, with not quite ten per cent, Spain fourth, with about nine per cent, and Canada fifth, with about eight per cent. It is only in comparatively recent years that the United States has attained its present importance as a lead-producing country. Although the first lead mining was done as early as 1621, the industry did not develop on a large scale until the latter half of the nineteenth century.

The West is generally regarded as the leading source, not only of gold and silver, but also of other metals, and it is probable that few persons outside the industry realize that the largest annual lead production in the United States and the largest total production to date have been in the regions east of the Rocky Mountains. The romance of gold and silver has somewhat obscured the prosaic part played by lead, but the production of lead in terms of dollars compares favorably with that of gold and silver. The total domestic production of gold up to date is valued at about $4,400,000,000 and that of silver at about $2,400,000,000, while the domestic production of lead, aggregating about 15,800,000 short tons, is valued at about $2,000,000,000.

[1] O. C. Harn, *Lead, the Precious Metal*, 1924.

Lead mining in the United States is, to a large extent, concentrated in four important districts.

One of the earliest lead-producing centers in the United States was the Upper Mississippi Valley, which includes small parts of Southwest Wisconsin, Northwestern Illinois, and a few counties bordering on the Mississippi River in Iowa. For the period 1842 to 1851, this district accounted for over eighty per cent of the total lead production in the United States. After the middle of the

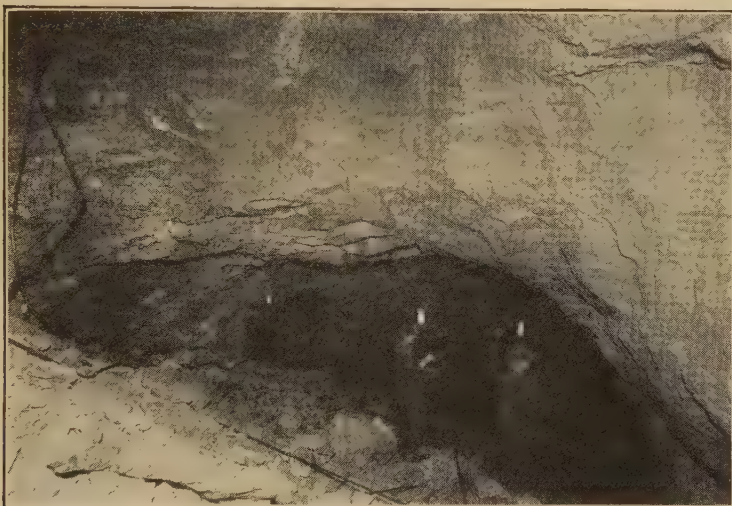


Fig. 1. — Flashlight of underground mining operations in Southeast Missouri district.

nineteenth century, however, production from this region greatly decreased and its importance as a source for lead is, at the present time, not very great.

The Lower Mississippi Valley District, which includes Southeast and Central Missouri, is an important lead-producing region. It was in this district that the existence of the famous disseminated lead deposits of Southeast Missouri at deep levels was first demonstrated in 1869 by the use of the diamond drill. This district reached its maximum production, 209,371 short tons, in 1925, accounting in that year for about one third of the total lead production in the United States.

The Southwest Missouri or Joplin District extends into three states and includes Southwest Missouri, Southeast Kansas, and

Northeast Oklahoma. Although the lead production of this section has been an influential factor in the market, the Joplin district is famed chiefly as a source for zinc.

The ores of the Mississippi region are practically non-argentiferous, that is, they do not carry sufficient silver to make its recovery profitable, nor do they contain any of the undesirable impurities, such as antimony, bismuth, and arsenic.

The Western District is second only to the Lower Mississippi Valley region in its lead production. The discovery of lead mines in the West came somewhat later than that of the Mississippi region, the first important discovery being made in Little Cottonwood Canyon, Utah, in 1863. The deposits at Leadville, Colorado, were discovered in 1874 and the Cœur d'Alene district about 1884. Later discoveries were made in New Mexico and Arizona. Idaho and Colorado were at one time the leading lead-producing states of the west, but Utah has since overtaken them and is now second only to the State of Missouri.

Prospecting. In the pioneer days only gold and silver were sought for, since they were easier to extract and brought much higher prices. Lack of adequate transportation facilities made mining of the so-called baser metals unprofitable. Since then the western part of the United States has become covered with railroads and highways. The chances for discovering virgin bonanza ore bodies at the surface are no longer as promising as they used to be. The old type of prospector has passed away, and his methods, more romantic than effective, have given way to the scientific accuracy of modern invention.

The rich surface silver-lead mines of the West have been either exhausted or worked to deeper levels. At the present time, the common practice of prospecting the mines of the West is by tunnels and drifts.

A great forward step in the development of methods of prospecting was the invention of the diamond core drill, now used extensively for the exploration of bedded ore deposits. The diamond core drill was invented about 1863 by R. Leschot, a French engineer. It was probably first used in this country for prospecting in the Pennsylvania coal fields and later in the Michigan copper and iron regions. The value of the diamond core drill is well known, and it is now widely used in prospecting for minerals, coal, and oil. It is a rotary type of drill using hollow drill rods,

on the bottom of which a hollow core barrel is fastened; on the bottom of the core barrel is a ring-shaped bit set with black diamonds (carbonados), which serve as the cutting medium. When the core barrel is filled, the entire string of drill rods, core barrel, and bit, is lifted from the hole for the removal of the core. It is capable of drilling to depths of several thousand feet. For mineral prospecting the cores usually range from three quarters of an inch to three inches in diameter. The core recovery depends upon the character of the formations being drilled and to some extent upon the skill of the driller. Under favorable conditions it is possible to make a complete recovery of the core. The diamond core drill is also frequently used for prospecting from underground workings and drifts, and for locating ore bodies which may be displaced by faulting. It was first introduced into the Southeast Missouri district by the St. Joseph Lead Company about 1869 for exploring the disseminated ore deposits, and to this invention must be given much of the credit for the rapid exploration and development of the disseminated ore bodies in that district. In the Southeast Missouri district, the diamond drill has been used almost exclusively for exploring the disseminated ore deposits. It has also played an important part in the development of many other mining districts. While the diamond drill has been greatly improved mechanically, the principles of its operation have not materially changed.

The principle of the churn drill, or well drill, is said to have been applied by the Chinese in the days of Confucius. It was probably first used in the United States for water wells, and about 1859 for oil well drilling. Its introduction for prospecting for minerals was a later development. The churn drill derives its name from the fact that the drill-bit is operated with an up-and-down motion, similar to that of the old-fashioned hand churn. In the Joplin and Upper Mississippi Valley regions this churn drill has been the only type used for prospecting. The large porphyry copper deposits of the West were also largely explored by means of this drill. Originally, the churn drill was a stationary, immobile affair, while the modern type is mounted on wheels and equipped with gasoline motor and is capable of moving over rugged country under its own power. In some cases, either the diamond or churn drill may be used, but frequently conditions are encountered where

diamond drilling is practicable and churn drilling impracticable, and *vice versa.*

Prospecting by the larger mining companies is guided mainly by the results of geological study and projection. While the geologists cannot always determine where the ore is, nor even where it is not, they can usually determine where it is most likely to be found.

More recently, geophysical survey methods have received serious consideration as a guide in carrying out the better known methods of prospecting, especially where there is an absence or a complication of geological information. Among these methods are the electrical, magnetic, seismic and gravimetric, based upon the respective electrical, magnetic, elastic, and gravimetric properties of the ore and their surrounding rocks. These methods are based upon strictly scientific principles and involve the use of highly sensitive and specially constructed instruments. For their success they depend to a great extent upon a correct interpretation of the indicated results and the correlation of such results with available geological information. At the present time these methods are being employed principally in prospecting for ore bodies of the massive sulfide type which lie relatively close to the earth's surface. While still largely in the experimental stage, geophysical survey methods have shown sufficient advance to hold out great promise for future development.

Mining. Mining is the process of actually digging the ore out of the ground and bringing it to the surface. Lead is found in the earth in various ores, most important of which is galena (lead sulfide). The only other ore of any commercial importance is cerussite, natural lead carbonate. It is usually found near the earth's surface below the ground-water level. Practically all the ore mined in the United States is the sulfide of lead. When cerussite or lead carbonate is found on the surface, it is usually, although not always, an indication that galena or lead sulfide may be found underneath.

In the early days of lead mining in the United States crude methods were employed. The equipment of the miner consisted of pick, wooden shovel, crowbar, sledge hammer, and occasionally, black powder. Transportation was by means of pack horse and cart. Ore was handled in boxes or sacks, and was either hoisted with a rope or carried from the mines. Water was handled by

iron or rawhide buckets suspended by a rope. The mechanical hoisting of ore and handling of water was accomplished first with the hand-operated windlass, next by the horse-pulled whim, and later by the steam hoist and steam pump driven by a steam engine. All-wood mine cars and wood rails supplanted the box and raw-hide sack for handling ore in the mines. Dynamite succeeded black powder. The means of transportation were improved. Larger mine cars were brought into use, first operated by the workmen, then by mules, and later by locomotives. The air-operated machine drill superseded the hand drill. The iron hoisting bucket was succeeded by the cage for handling cars from mine to surface, and later the skip hoisting equipment was developed. The hand shovel has, to a large extent, been superseded by mechanical loading machines. The individual steam power plant has given way to the central electric power plant with electrically operated hoists, compressors, pumps, and motors for underground haulage. Other improvements include larger shafts, central shaft hoisting, multiple car tipples, electric lighting, automatic hoists, and steam turbines for power.

At the present time, mining in the Southeast Missouri district is confined almost entirely to the disseminated ore deposits, which occur at depths ranging from one hundred to seven hundred feet from the surface. The ore bodies are of the horizontal or blanket type, ranging from a few feet to more than a hundred feet in thickness, from twenty-five feet to several hundred feet in width, and usually several thousand feet in length. These ore bodies are mined by the room and pillar system. No timbering is required, as the roof is supported by massive pillars of undisturbed rock sometimes as much as one hundred feet in height. As a result of mining these deposits, enormous underground caverns are created. At one point, where the underground workings of two of the mining companies are connected, these underground caverns can be traversed for a distance of approximately three miles. The drilling is done by air-powered machine drills. Electric underground haulage is used almost exclusively. Water is handled by electric pumps and hoisting is done with large electric skip-hoists. The tendency has been toward central shaft hoisting. About five thousand tons of ore are now being hoisted daily at each of two central hoisting shafts of the St. Joseph Lead Company. The mines of the St. Joseph Lead Company are

equipped underground with a standard railroad type of haulage system, which includes its standard block signal system. Probably more than half of the ore mined in the district at the present time is loaded by mechanical loading machines. The ore drills easily and breaks readily, and with the large stopes and the handling of large tonnages with modern mechanical methods and practices, low mining costs are obtainable.

In the western region the ore deposits are of varying types, but are most often in the vein formation, ranging in position from vertical to horizontal. Steeply inclined or entirely vertical veins are usually mined by the overhand stope method or by the underhand stope and shrinkage method. The walls are supported by timbers and by back filling with mine waste rock. Tunnels are sometimes driven primarily for prospecting purposes, and other times purely for drainage and haulage purposes, but they serve all of these purposes when ore is developed and mining operations are begun. Frequently these tunnels extend for several miles. Some of the mines have been worked to depths of more than three thousand feet below the apex of the ore bodies. Where mines are at great distances from transportation systems, aërial tramways are constructed. These tramways are sometimes several miles in length and are used for the transportation of the ores from the mines to mill, smelter, or railroad, and for the delivery of supplies to the mine.

The character of the ore deposits of the West as a rule necessitates expensive methods of development and mining. For this reason, the cost of mining in the West is generally higher than in the Mississippi Valley regions. The high-grade oxidized ores that were found near the surface and which could be easily and cheaply mined, have been largely exhausted. It has become necessary to mine the sulfide ores of lower grade and of varying degrees of complexity at deeper levels, with the attendant water problems and more costly mining methods. This condition has made large-scale production an economic necessity, and has brought about a greater concentration of ownership in the industry.

Milling. The process of treating ores by mechanical means for the separation of the valuable minerals from the gangue of rock into their separate concentrate products is commonly called "Milling," although "Concentrating" or "Ore Dressing" is probably a more accurate and comprehensive term for the processes involved.

In the natural mineral deposits, minerals containing zinc are often associated with minerals containing lead, so that milling practice is, in a general way, similar for both lead and zinc ores. Where lead and zinc occur together, selective treatment is necessary for the separation of the respective minerals. Milling as applied to the treatment of lead ores or lead-zinc ores involves crushing, sizing, jigging, tabling, grinding, classification, and flotation. Milling practice may vary considerably with different districts as the practice followed in any given district is dependent upon the character of the prevailing gangue material and the manner in which the valuable minerals are distributed throughout the mass of ore. In the case of the simple ores having low specific gravity gangue materials, the bulk of the valuable minerals is recovered by crushing the ore-bearing rock into fine particles and submitting it to gravity methods, such as jigging and tabling. The mechanical agitation causes the lighter particles to separate from the heavy particles of ore which contain the lead. This is the oldest and simplest form of concentration.

The important developments in milling practice during the past thirty years include the Wilfley tables, invented about 1896, which make the ordinary gravity method much more effective; improved and more efficient types of crushing and grinding machinery; mechanical means of handling materials; and, most important of all, the introduction of the flotation process.

The introduction of the flotation process has undoubtedly been the most radical advance in milling practice in the twentieth century. Flotation is not dependent upon a difference in the specific gravity of minerals to be separated. For example, the sulfide minerals, which are usually heavier than the gangue, are floated, while the lighter gangue material remains in suspension. A distinction must be made between ordinary flotation and selective or differential flotation. Ordinary flotation is the process of separating the valuable minerals from the gangue. Selective flotation goes a step further and separates the various constituent metals from each other.

The flotation process will operate satisfactorily only on finely ground materials. Even the experts most intimately associated with the flotation process have not as yet clearly perceived the underlying principles, but the present conception is that certain native metals and metal sulfides have a greater attraction for

certain oils or chemical compounds than have their accompanying rock or gangue minerals. The flotation process consists in the agitation of finely divided ore in water containing bubbles of air or gas and a small amount of oil and, usually, other chemical compounds. The oil and chemical compounds have an affinity for the valuable metals or minerals and coat the metal or mineral particles in preference to the gangue material. A second attraction of the oil and chemical compounds exists for the small bubbles of air or gas passing upward from the pulp mass. With this double attraction, the valuable metal or mineral particles are attached to the air or gas bubbles and are thereby carried to the surface of the pulp mass and form a froth or scum, which, when removed from the surface of the pulp, forms a concentrate containing the valuable metals or minerals.

The ordinary flotation process was discovered about 1905 and its early application was made principally in Australia. Although the process was introduced into this country about 1911, it did not come into general use until about 1913. Differential or selective flotation was first introduced in the United States about 1921, but did not find favor among the mining companies until several years later.

Since its introduction in this country, flotation has had a phenomenal growth. Data compiled by the Bureau of Mines show that in 1924 about 95% of copper ores, 28% of the lead ores, and 6% of the zinc and zinc-lead ores in the United States were treated by ordinary flotation. In 1919 about 26,000,000 tons of ore were treated by the flotation process and by 1925 the tonnage treated had nearly doubled. The increase since 1925 has been at an even greater rate.

Selective flotation did not come into general use until about 1925, but it has since then been spreading so rapidly throughout the country, that it has had a considerable effect in the increased production of the three principal ores involved — lead, zinc, and copper.

In the Rocky Mountain region there are large deposits of refractory or the so-called complex zinc-lead-iron sulfide ores. These ores carry relatively high percentages of lead and zinc sulfides. The lead-and-zinc minerals in some of these ores are crystallized closely and so intimately associated that they can be separated from each other only by very fine grinding. Efforts

to concentrate these complex ores by mechanical methods have yielded very little success.

On account of the large amount of zinc in the ores purchased by the western smelters, the smelters found it necessary to penalize the zinc content of ores in excess of certain stipulated percentages, and because of the heavy zinc penalty, it was found unprofitable to ship the complex ores to the smelters, except when the lead content greatly predominated or where the ores carried high precious metal values. Therefore, large deposits of complex ores lay dormant for years, and it was not until the development of differential flotation that they became available. Complex ores of the most refractory type are being successfully treated by differential flotation at the present time. Through this development deposits of complex ores, which were previously considered worthless, have become valuable, and thus the potential supply of non-ferrous metals has been materially augmented.

Smelting. Lead smelting is the art of treating lead ores and lead concentrates by fire processes for the extraction of the valuable metals. Refining embraces the treatment of the lead extracted by the smelting processes for the removal of all other metals, such as zinc, gold, and silver, and any remaining impurities.

At the present time only two types of furnaces for lead smelting are in general use in the United States — the ore hearth and the blast furnace. The ore hearth is employed only in the Mississippi Valley smelters for treating a part of the high-grade galena ores and concentrates originating in the Mississippi Valley regions, while the blast furnace is universally employed in all of the smelters throughout the United States. A small tonnage of primary lead ore is being treated by hydrometallurgical or wet methods. These methods are still in the experimental stage, and while they give promise of finding an important place in lead metallurgy, they have not as yet been successfully employed for commercial purposes.

The first smelting in the Mississippi Valley region was probably done by melting galena over a camp fire. The next step was the construction of a furnace by arranging two stones in the form of a V. This furnace was filled with wood and galena and the wood ignited. As heat developed, a part of the lead was reduced and recovered as metallic lead. Only a small part of the lead content was recovered by these crude methods. From

these primitive methods, the log hearth or log furnace was developed. The log furnace was usually located on the side of a hill having a slope of about forty-five degrees. The furnace consisted of a hearth of stone inclined with the hill, surrounded on its front and sides by a stone wall, while the top and back end of the hearth were left open. At the bottom of the hearth, an arch or opening, which formed the eye of the furnace, was made in the front wall. A hole was dug in the ground in front of the furnace,

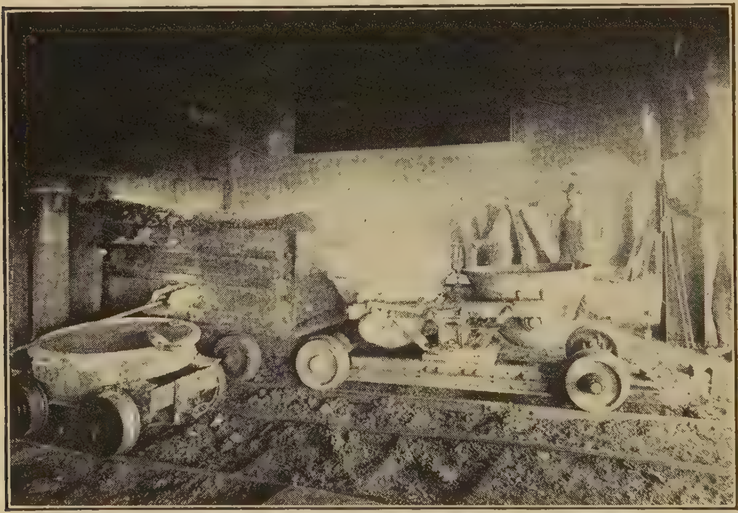


Fig. 2. — Blast furnace showing slag and mattes tap.

under the furnace eye, to receive the molten lead as it came out. A layer of logs forming a floor was placed in the furnace. These logs rested on ledges arranged on the walls to hold the logs above the hearth and to provide draft. Split logs were then set on end around the front and sides of the furnace. Galena was piled on until the furnace was filled; the galena charged usually amounted to about five thousand pounds. The furnace with its galena charge was then covered with logs and fired. A low heat was maintained at the start and gradually raised during the first twelve hours, during which time the furnace action was largely one of roasting, that is, burning off some of the sulfur. After the roasting period, a stronger heat was maintained for another period of twelve hours or longer, during which time the smelting action took place, reducing a part of the lead content of the galena to metallic

lead. The lead recovered in this type of furnace amounted to about fifty per cent of the lead content in the galena. Some of the lead was volatilized as fume and lost, while that unaccounted for by the lead recovered and lost by volatilization remained behind in the furnaces as a residue called " lead ashes." These were for a time considered worthless, but were later recovered in what was known as the " ash " furnace. The log furnace was probably

FIG. 3. — Reverberatory roasting furnace.

used as early as 1720, and all of the lead in Missouri was smelted in this type of furnace during the eighteenth century.

In 1850, the reverberatory furnace, patterned after European practice, was introduced. There were many types of reverberatory furnaces and practices. Galena ore was smelted directly in the reverberatory furnaces and, when the ore was pure, gave fairly good results. It is estimated that with pure galena ores the lead yield in the reverberatory practice ranged from eighty to ninety per cent of the lead contained in the ore. The reverberatory furnace was an improvement over previous practice, as it enabled the smelting of lower grade ores.

In the early seventies, the cupola furnace was introduced in the Missouri district. The cupola furnace process called for two

separate operations — roasting and smelting — and in this respect it differed from previous practice. The ore was first roasted in a separate reverberatory furnace, and the roasted ore was then smelted in the cupola furnace. About 1900, the cupola, or round blast furnace, was supplanted by the small rectangular blast furnace of the type now in use.

About 1870 E. O. Bartlett successfully introduced the practice of filtering furnace fumes through suspended cloth bags for the recovery of the fume and fine dust which failed to settle in the dust chambers or flues. This method of fume recovery became common practice wherever the recovery of fume was sufficient to justify the cost of installation and operation. It is known as the "bag house system" and, although improved in construction and mechanical details, the principle of its operation remains unchanged. The Cottrell process of electric precipitation has in recent years become prominent as an alternative to the bag house system for the recovery of smelter fumes and dust. The log furnace, the ash furnace, and the reverberatory furnace for smelting have all become obsolete.

The ore hearth or Scotch hearth, as noted above, remains an important part of the smelting practice in the Mississippi Valley. Since the middle of the nineteenth century, the ore hearth has continued in the Mississippi Valley regions practically without change. The principal objections to the hand rabbled ore hearth were the difficulty in obtaining skilled workmen to operate it on account of the hard manual labor required and the intense heat of operation. These objections were largely overcome by the development of the "St. Louis" hearth in 1916. The "St. Louis" hearth consists of a furnace, double the length of the old type, with mechanical means for rabbling and banking the hearth. With the same number of workmen, the St. Louis hearth has a smelting capacity of more than twice that of the old type of furnace. The conversion of the Scotch hearth from manual to mechanical operation has greatly increased its metallurgical efficiency, and decreased the cost of its operation by more than fifty per cent. These improvements in hearth practice were developed by A. S. Moses and W. E. Newnam of the St. Louis Smelting & Refining Company, a subsidiary of the National Lead Company. The ore hearth has been utilized principally for the smelting of lead sulfide ores and concentrates, but recently it has been found to be well adapted to the treatment of high-grade

oxides, carbonates, and sulfates. Present indications are that it will also have a broad field of use in the production of secondary lead by treatment of by-products, residues, and scrap materials high in lead content.

The present century has witnessed the abandonment of the hand-raked reverberatory furnace (for roasting ores preceding their smelting in the blast furnace) and the substitution of mechanical roasters. The Huntington-Heberlein pot-roasting process (preceded by a preliminary roast in a mechanical furnace) was introduced about 1906 and the Dwight and Lloyd sintering process about 1910. The present practice includes a double roast, the preliminary roast being made on Dwight-Lloyd machines and the final roast either on Dwight-Lloyd machines or in Huntington-Heberlein pots. Further progress during the present century has been made by the use of larger blast furnaces, improved furnace construction, mechanical furnace-charging systems, larger bag house installations, the adoption of labor-saving devices, and the use of mechanical means of handling materials.

Refining. The production of commercial refined pig lead requires the removal of the following metals, when present in the crude lead or base bullion in detrimental quantities: arsenic, antimony, tin, zinc, silver, gold, copper, and bismuth.

Several thousand years ago it was discovered that lead was considerably improved by stirring the hot molten mass with a pole and skimming off the dross that was formed on the surface. This operation removed the first four metals listed above, along with some of the lead. Later on, the process of oxidation was continued until practically all the lead was also removed, leaving the much-sought-for silver and gold behind. Copper and bismuth cannot be entirely removed by oxidation, but by careful liquation the copper content can be materially reduced.

The process of oxidation by cupellation or softening was the universal method of refining until Hugh Lee Pattison discovered, in 1833, that bismuth, gold, and silver, could be removed by repeated crystallizations, since the lead crystals are purer than the remaining liquid. The Pattison process came into general use in Europe and was continued for many years after the Parkes process was introduced.

Karsten discovered in 1842 that gold, silver, and copper could be removed by the addition of a small percentage of zinc, but his

discovery could not be applied in practice until A. Parkes found the means (1850-52) of working the zinc-silver-lead crust and refining the " zincky " lead. The Parkes process has now been a standard method of desilveration for about sixty years. In both the Pattison and Parkes processes, softening and cupellation were retained as necessary adjuncts.

An electrolytic process for the refining of lead, employing an electrolyte containing lead fluosilicate and free hydrofluosilic acid was worked out by Anson G. Betts about 1900. A small

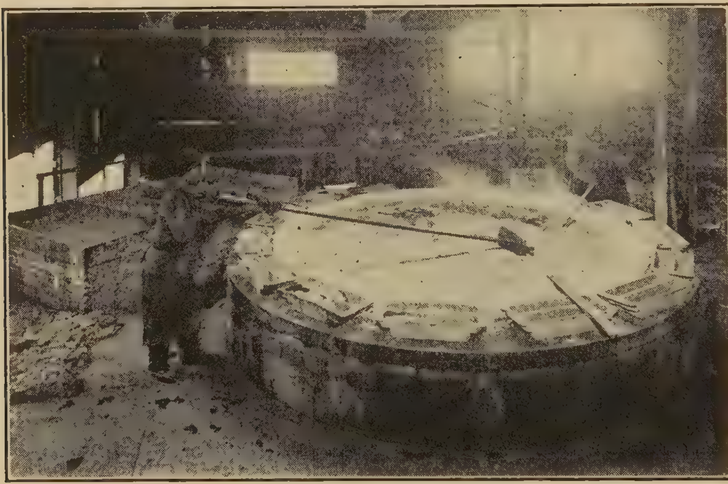


FIG. 4.—Lead refinery desilverizing kettle.

tonnage is being treated by this process at the present time. The latest innovations in the refining of lead are the Harris and Thompson processes for the removal and recovery of arsenic, antimony, and tin, supplanting the softening and the Betterton processes for the removal and recovery of zinc as a chloride.

The principal chemical developments in lead refining have been the Parks, Betts, Harris, and Thompson processes referred to above. There has likewise been greater efficiency on the mechanical side. Some of the important improvements are the Steitz syphon for transferring molten lead from kettles or furnaces, which was later largely supplanted by the centrifugal pump; the Howard zinc stirring machine; the Howard skimmer; the Howard dross press; the straight-line casting machines of the Miller and Omaha types; the Newnam pig puller and stacker

for use in connection with the moulding wheel; and electric lead trucks of the Omaha and Newnam types for handling lead in stacks of thirty-six to forty pigs.

Secondary Lead. The value of secondary lead recovered in 1926 amounted to about $35,000,000.00. With the exception of the pig lead consumed in the manufacture of white lead and other paint pigments, the bulk of the production of lead which goes into lead products is ultimately recovered in the form of drosses, old metals, and alloys of various kinds. The secondary lead business is a subdivision of the larger industry of the collection of waste material estimated to have a value of more than a billion dollars a year. The waste material collected by the small junk dealer is sold to the larger junk dealer and by him to the large smelters. Some smelters restrict themselves to secondary metals, but the large smelters which treat lead ore also recover some lead from scrap and drosses. The following figures indicate this division:

Secondary lead recovered in the United States, 1924–1925, in short tons: [1]

	1924	1925
Secondary lead recovered by smelters that treat mainly ore	31,398	35,146
Secondary lead recovered by smelters that treat only scrap and drosses	59,002	77,274
	90,400	112,420
Secondary lead recovered in remelted alloys:		
Lead content of antimonial lead scrap treated at regular lead smelters	6,630	9,483
Lead content of drosses and scrap alloys treated at secondary smelters	107,470	104,977
	114,100	114,460
Total secondary lead recovered	204,500	226,880

The term "secondary" does not necessarily indicate that secondary metals are of an inferior quality, providing adequate refining methods are used. For many purposes either primary or secondary lead may be used to equal advantage. The introduction of the Harris and the Thompson Processes will further the status of secondary lead, since these processes make available for uses of all kinds the metal contents in lead alloys which previously could not be successfully and profitably separated. These processes

[1] Figures taken from "Secondary Metals in 1925, Mineral Resources of the U. S. 1925, Part I," Gov. P. O. 1927.

are of a chemical nature and separate the alloys containing lead, silver, tin, antimony, arsenic, etc., by succesive steps so that the process may be stopped whenever desirable. For instance, if an alloy contains lead, tin, and antimony, the tin may be removed, leaving lead and antimony, which is marketable as antimonial lead; or the process may be carried a step further and the antimony extracted, leaving the lead pure for all commercial purposes. The great obstacle in the use of such lead alloys in the past was the inability to cope with the presence of arsenic. The Harris and the Thompson Processes have to a great extent overcome this difficulty. Dr. G. W. Thompson, Chief Chemist of the National Lead Company, and Henry Harris of London were the originators of these processes, which, like a great many other inventions, were developed simultaneously but entirely independently of each other.

Tariff Policy and Prices. The tariff on lead goes back to the Act of August 10, 1789, when a duty of 1¢ per pound was included to cover "bar and other lead." This superseded the first tariff act of July 4, 1789, under which lead was admitted free of duty into the United States. No distinction was made between lead ore, lead bullion, and pig lead, nor were the products manufactured only partly of lead included. By the Act of March 2, 1791, however, the duty was extended to "all manufactures wholly of lead or in which lead is the chief article." The ambiguity in the phrasing of the law did not raise any serious obstacles, because up to about 1880, there was practically no importation of lead-bearing ore into the United States. The Act of March 3, 1883, was the first to introduce a tariff of 1½¢ per pound on "lead ore and lead dross," while the same Act permitted the importation free of duty of both gold and silver ores. In 1886, large quantities of lead ore, which contained a considerable amount of silver, began to be imported from Mexico. In terms of value, the silver predominated over the lead, and a ruling was obtained from the Treasury Department permitting the import of this ore free as silver rather than as lead ore. This ruling raised great dissatisfaction among lead producers and a heated controversy followed. This feeling was not allayed until the passage of the McKinley Act in 1890, which made lead ore dutiable at 1½¢ per pound provided that "silver ore and all other ores containing lead shall pay a duty of 1½¢ per pound on the lead contained therein, according to sample and assay at the port

of entry." To counterbalance the victory of the lead producers, a concession was made to the lead smelters by the provision that ores and metals might be imported and refined in bond in the United States. As a result the smelters were enabled to obtain additional ore for fluxing purposes and also to reduce their unit overhead expenses by a large smelting tonnage. Although there have been several modifications in the provisions of this section of the law, the general effect has not been changed. Under the latest tariff act, an amount of lead equivalent to the quantity imported must be exported to avoid the payment of a duty. Lead manufacturers may import lead bullion; but in order to avoid paying the duty, the imported lead must be identified as the lead which enters into the manufacture of the product which is exported.

The various tariff acts since 1890, with the exception of the Act of 1913, have maintained a duty on lead of 2¢ or more per pound. The Act of October 3, 1913, imposed an *ad valorem* rate of 25% on all lead commodities, excepting the ore, which was subject to a duty of $\frac{3}{4}$¢ per pound on the lead contained therein. The 25% *ad valorem* averaged approximately $\frac{3}{4}$¢ per pound. The Tariff Act of 1922, which is still in effect, contains the following provisions with respect to lead:

Customs Duties on Lead

Par. 392. Lead-bearing ores and mattes of all kinds, $1\frac{1}{2}$¢ per pound on the lead contained therein: Provided, That such duty shall not be applied to the lead contained in copper mattes unless actually recovered: Provided further, That on all importations of lead-bearing ores and mattes of all kinds the duties shall be estimated at the port of entry and a bond given in double the amount of such estimated duties for the transportation of the ores or mattes by common carriers bonded for the transportation of appraised or unappraised merchandise to properly equipped sampling or smelting establishments, whether designated as bonded warehouses or otherwise. On the arrival of the ores or mattes at such establishments they shall be sampled according to commercial methods under the supervision of Government officers, who shall be stationed at such establishments and who shall submit the samples thus obtained to a Government assayer, designated by the Secretary of the Treasury, who shall make a proper assay of the sample and report the result to the proper customs officers, and the import entries shall be liquidated thereon. And the Secretary of the Treasury is authorized to make all necessary regulations to enforce the provisions of this paragraph.

Par. 393. Lead bullion or base bullion, lead in pigs and bars, lead

dross, reclaimed lead, scrap lead, antimonial lead, antimonial scrap lead, type metal, Babbitt metal, solder, all alloys or combinations of lead not specifically provided for, $2\frac{1}{8}$¢ per pound on the lead contained therein; lead in sheets, pipe, shot, glazier's lead, and lead wire, $2\frac{3}{8}$¢ per pound.

Par. 47. Lead: Acetate, white, $2\frac{1}{2}$¢ per pound; acetate, brown, gray, or yellow, 2¢ per pound; and all other lead compounds not specially provided for, 30 per centum ad valorem.

Par. 74. Lead pigments: Litharge, $2\frac{1}{2}$¢ per pound; orange mineral, 3¢ per pound; red lead, $2\frac{3}{4}$¢ per pound; white lead, $2\frac{1}{2}$¢ per pound; all pigments containing lead, dry or in pulp, or ground in or mixed with oil or water, not specially provided for, 30 per centum ad valorem.

After deducting freight and insurance, the net margin between the price of foreign lead and that in the United States possible under the tariff is about $1\frac{1}{4}$¢ per pound. It follows, therefore, that unless there is an overabundance of lead produced within the United States, the price of pig lead may be kept $1.25 per hundred pounds above the London price, without making importation of lead ore profitable. This differential has varied in the past, fluctuating in proportion to the tariff in effect, which has been as high as 3¢ per pound on bullion lead from 1828 to 1846 and as low as 15% ad valorem from 1857 to 1861.

The following Chart (I) pictures the relationship of the lead prices in the three leading markets of the world — London, New York, and St. Louis — to the prevailing duty over a period of one hundred and fifteen years, 1812 to 1926, enabling the reader to correlate the price differentials with the existing tariff on lead bullion and lead in ore.

The price of lead has, with one or two exceptions, always been lower in London than in New York, the differential in most years being a considerable portion of the price of lead. This is due to some extent, at least, to the fact that lead can be produced more cheaply in Mexico, Europe, and Australia, than in the United States. It is conceded that the tariff on lead has raised the price of the metal, but it is argued by those in favor of the tariff that the beneficial results, such as the great stimulation to domestic production and the employment of domestic labor and capital, have more than counterbalanced the unfavorable effect of the higher cost of the metal to the ultimate consumer.

A more detailed picture of the relationship of prices in London, New York, and St. Louis is presented in Chart II, which gives the

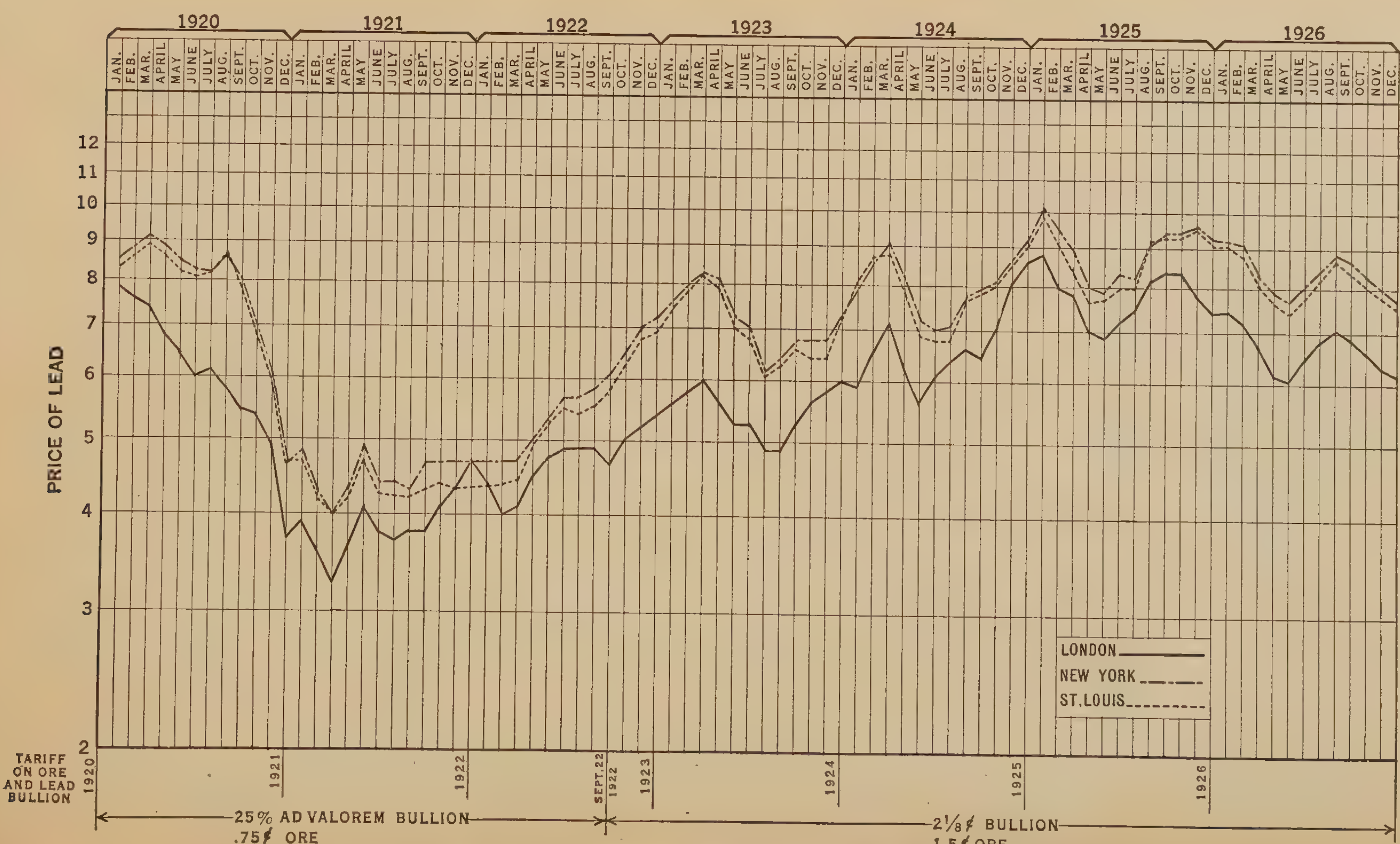


Chart II.—Monthly average price of lead in London, New York, and St. Louis.

monthly prices in the three markets for the years 1920 to 1926 and the tariff rate in effect during that period.

In December, 1921, we had the unusual condition of the London price being above the St. Louis price. This condition was due partly to the rise in Sterling and partly to the weakness of the market in the United States.

> "Lead is strong in European markets, particularly for spot delivery and with the advance in Sterling computations on Monday indicate that lead from producers in the northwest might be shipped from the Panama Canal to London with approximately the same return as if sold in this country. Of course, all Mexican lead has gone abroad for some time." [1]

The St. Louis price is ordinarily 10¢ to 25¢ lower than New York, the difference being accounted for mainly by the cost of transportation from St. Louis to New York. Occasionally, New York is lower than St. Louis. Such reversal is due to the fact that lead is either being imported from Europe or else the threat of such a possibility depresses the market price in New York. Accurately expressed, a decline is brought about in the New York price rather than a rise in the St. Louis price.

Charts I and II show that with some exceptions the price of lead in New York is usually above the London price by at least the amount of the duty. What are some of the effects of this increased price of lead in the United States? In the first place, it raises the cost of the raw material to the manufacturers of lead products in the United States and therefore ultimately to the consumer. It also lowers the cost of raw materials to manufacturers of lead products in European countries, since the tariff on the import of lead into the United States keeps the imports of lead down to a minimum and thus increases the supply available for other countries. In the second place, the tariff on lead raises the domestic prices for lead and therefore encourages the exploitation of the lower-grade mines, thus increasing the amount of ore which comes on the market.

It is also an important factor in the development of the mining and smelting industry and the production of gold, silver, zinc, and copper, which are often found in the ore combined with lead, since the larger the amount of ore that is available for smelt-

[1] *The Engineering and Mining Journal*, December 17, 1921.

ing, the lower the costs of smelting. This seems to be the position taken by the United States Tariff Commission:

"The duty on the metal is therefore compensatory. It has indisputably raised the price of the metal to the consumer, but has greatly stimulated the domestic production, especially at the period when the latter began to be obtained largely from low-grade ores. Without such tariff protection the production of ore and metal would undoubtedly have been seriously checked at certain periods of depression." [1]

In spite of the high level of prices in the United States, due partly to the tariff, comparatively few discoveries of new lead mines have been made in the last few years. As a result, low-grade mines, which would be unprofitable were it not for the tariff, continue to be operated. The effect has therefore been to exhaust the lead resources of the United States at a more rapid rate than would take place in the absence of a tariff.

Marketing of Lead. New York and St. Louis are the two major markets for lead in the United States. According to Mr. I. H. Cornell [2] "at least one half of the lead produced in the United States is sold at a price based upon some average price, the standard basing prices being the New York and St. Louis prices of the Engineering and Mining Journal [3] and the American Smelting and Refining Company's 'official' average prices."

There are many kinds of pig lead marketed in the United States, but the four leading grades are corroding lead, chemical lead, common desilverized lead, and soft Missouri lead. Corroding lead is used for the manufacture of white lead and is the purest refined lead made. It commands a premium of 10¢ a hundred pounds and, in some cases, 15¢, over common lead. (There are no intermediate prices between 10¢ and 15¢.) The requirements are very strict, since a very small amount of silver will cause a pink shade in white

[1] *Tariff Information Survey* — Government Printing Office, 1921.

[2] Vice-Pres. and Sales Manager of the St. Joseph Lead Company.

[3] "The most concise explanation of the basis of these quotations is the following which appears as a footnote in the weekly issues of the Engineering and Mining Journal: 'The above quotations are our appraisal of the average of the major markets based generally on sales as made and reported by producers and agencies, and represent to the best of our judgment the prevailing values of the metals for deliveries constituting the major markets. The quotations are arrived at by a committee consisting of the market editors of Mining Journal.'"

lead; bismuth will give white lead a grayish tint; copper a green tint; and iron a red tint. Corroding lead is made by submitting ordinary lead to a separate refining process for the purpose of eliminating bismuth. Chemical lead which is produced from the Southeast Missouri ores contains small quantities of silver and copper, but is free from bismuth. Because of the fact that it withstands the corroding effects of acids of all kinds it is used for lining tanks in chemical processes, but it has many other uses. Common desilverized lead is made from the silver lead ores coming from the Rocky Mountain States. Soft Missouri lead, which comes from the Joplin district, is almost entirely free from silver.

There is a division in the lead-mining and smelting industry between miners and smelters. In recent years, however, some of the large mining companies, such as the Bunker Hill and Sullivan Mining and Concentrating Company and the International Lead Company have built their own smelting plants; but there are hundreds of small miners throughout the United States who sell their ore to the large smelters, such as the American Smelting and Refining Company on a contract at stipulated prices. The American Smelting and Refining Company and the other smelters in turn, sell the finished pig lead to the consumer.

The practice followed by all the large mining and smelting companies in the United States is to sell only for direct consumption. The companies will not sell in any considerable quantities to dealers for resale, nor will they deal on a Metal Exchange. Such an attitude accounts for the ineffectiveness of the New York Metal Exchange, which is at the present time an exchange in name only. Practically no transactions in lead, zinc, or copper ever take place on the New York Metal Exchange and only comparatively minor ones in tin. In former years, the New York Metal Exchange was a real factor in the price determination of the non-ferrous metals and its quotations reflected the actual transactions of those actively engaged in the business.

About three years ago, the Engineering and Mining Journal Press sent out letters to the leading metal producers and consumers in the United States requesting an opinion as to the advisability of establishing a strong metal exchange in New York City. The replies are recorded in "The Marketing of Metals and Minerals."[1] Under the heading of "The Case For and Against

[1] Spurr and Wormser, *The Marketing of Metals and Minerals*, p. 632, 1925.

a New York Metal Exchange" the positions taken are clear cut. The producers and smelters are invariably opposed to a metal exchange, whereas the consumers favor it. The following quotation is representative of the attitude of the producers: "Our policy is so directly contrary to selling on a metal exchange that, so far as we are concerned, no metal exchange can expect support from us. Our endeavor is to sell direct to the consumer and in no case to sell him more than he expects to use at the time of purchase." The other side of the question is expressed by a large consumer who has had experience with the workings of the New York Metal Exchange: "I feel that, as this country is the principal producer of practically all metals (except for tin, of which it is the largest consumer), prices should be established in this country on the basis of trading on exchange, rather than to depend on the London Exchange." [1]

The New York Metal Exchange was organized and incorporated under the laws of the State of New York in 1883. For many years it was an active exchange with a building of its own at Burling Slip and Pearl Street, and a membership which included all of the important producers and consumers of metals. The number of traders was large, for this was the day of the comparatively small producer and consumer. But with the movement toward large combinations in the late '90s and early 1900s among the mining producers and smelters comes the decline in the amount of business transacted on the New York Metal Exchange.

Several attempts were made to resuscitate the New York Metal Exchange. The latest attempt of this kind was made in 1922. The Rules of the New York Metal Exchange were completely revised so as to make them conform to the requirements of present conditions. The producers of metals took no part whatever in this attempt to reëstablish the New York Metal Exchange and continued to restrict their sales to consumers only. The result was that this final attempt to reëstablish the Metal Exchange was a complete failure. The producers feel that it is to their interest to sell directly to consumers, and only for immediate consumption, refusing to sell "futures." In this way they are in a position to prevent speculators from cornering or controlling the market, avoid intermediate handling, and also do away with the broker's or middleman's profit.

[1] Spurr and Wormser, *The Marketing of Metals and Minerals*, p. 641, 1925.

In organizations the lead industry is very compact. About twenty-five mining companies in the United States produce more than 90% of the lead and about five companies do over 90% of the smelting. The largest factor in smelting is the American Smelting and Refining Company, with a smelter production of 469,607 short tons in 1926.

The important companies selling pig lead in the United States are the following:

American Smelting and Refining Company
St. Joseph Lead Company
United States Smelting, Refining and Mining Company
United Metals Selling Company (controlled by Anaconda)
DesLoge Consolidated Lead Company
American Metal Company
Bunker Hill and Sullivan Mining and Concentrating Company

The purchasers and consumers of lead are, of course, much more widespread than the producers and sellers of the metal, although there are some large buyers, such as the National Lead Company, which is the largest consumer of lead in the United States; the American Telephone and Telegraph Company, which buys lead for its cable coverings; the General Cable Company, which also uses it for cable coverings; the many storage battery and automobile companies; the large ammunition companies; and the railroads. In addition, there are thousands of consumers who buy lead for building, bearing metal, solder type metal, lead foil, plumbing supplies, and for many other uses.

Labor Conditions. A discussion of labor conditions in the lead mining and smelting industry may be roughly divided into three periods. There was the early period in the '60s and '70s when mining was done to a great extent by individuals on their own account, the leasing system being generally practiced. The laborers employed were, in many cases, farmers and lumbermen who worked as miners during part of the year. This condition is illustrated in a letter from Mr. H. D. Heltzell, formerly Secretary of the Granby Mining and Smelting Company, " The employees and townspeople generally of Granby were allowed to graze their livestock on 1000 acres of Company property which were not fenced in or leased out for farming purposes. . . . About the only time we had any discontent at the smelter was during the early spring months when the men wanted to make their garden

and during July and August when they much preferred to work with the neighboring farmers in the harvest fields and we always arranged our business affairs so that during these periods we would close down the smelter for overhauling and repairs." [1]

The second period in the development of labor problems in the industry covers the '80s and '90s and early 1900s. It is generally understood that the labor problems become most acute in periods of depression, since the trade unions are always opposed to a reduction in wages. The panic of 1893 closed many mines, resulting in a lowering of wages. The Western Federation of Miners grew out of the Idaho strike in 1892, but did not become fully organized until May 15, 1893. This union began on a small scale, but gradually increased in power until it became an industrial organization of "all the workers in and about the mines." [2] In 1896 it affiliated with the American Federation of Labor; but the affiliation was severed in 1898, since the policies of the two organizations differed in many respects. The Western Federation of Miners took an active part in radical politics. It was instrumental in organizing the Industrial Workers of the World and remained an important part of it for several years. However, since most of the members in the Western Federation of Miners disapproved of the activity of the Union in radical politics, it was decided in 1911 to reaffiliate with the American Federation of Labor. This reaffiliation displeased the more radical members of the union and caused some internal dissension, resulting in a number of secession movements fostered by the Industrial Workers of the World. The membership of the Western Federation of Miners from 1897 to 1914 was as follows:

[1] Letter to the writer dated May 16, 1927. The close connection between farming and mining has left its effect on mining terminology. The word "pig" indicates the casting of lead from the smelter and is borrowed from the early vocabulary of the iron industry. The iron industry was one of the first developments of the period known as the industrial revolution and in the period of transition the men were both farmers and industrial workers. It was thus natural for them to express their observations in the factory in the terms of the farm. The channel conducting the molten iron from the furnace to rows of molds connected by short slender ducts reminded the workmen of a sow feeding her young. They therefore called the main channel the "sow" and the small molds feeding thereat the "pigs." The arrangement in a lead smelter is quite different, but the term "pig" lead has nevertheless been carried over.

[2] Bureau of Labor Statistics Bulletin 420, Oct. 1926, pp. 98–99.

Miners, Western Federation[1]

1897	1898	1899	1900	1901	1902	1903	1904	1905	1906
8000	10000	12000	14000	17700	19600	28300	24100	26300	28600

1907	1908	1909	1910	1911	1912	1913	1914
44200	30500	35300	37100	50200	49200	49500	36900

The secession of the radical elements of the Western Federation of Miners left the more conservative workers in control. In 1915 the name was changed to the International Union of Mine, Mill, and Smelter Workers, and its jurisdiction extended from the metal mines in the Rocky Mountain district to the entire United States and Canada to cover smelters, refineries, and blast furnaces as well as mines. One of the specifications for membership is that no "individual holding membership in the Industrial Workers of the World or in any union not recognized by the American Federation of Labor shall be admitted to membership until he surrenders such other membership; and any member of the International Union of Mine, Mill, and Smelter Workers who becomes a member of the Industrial Workers of the World or any union not recognized by the American Federation of Labor, shall forfeit his membership in the International Union of Mine, Mill, and Smelter Workers." The membership in this union from 1915 to 1923 was as follows:

Mine, Mill, and Smelter Workers[2]

1915	1916	1917	1918	1919	1920	1921	1922	1923
16700	16100	17900	16700	17800	21100	16200	4600	8100

The present membership is probably less than that of 1923, which was then 8100. Since it is estimated that the number of men employed in these industries approximates 200,000, the union membership represents approximately 4% of the workers. For all practical purposes, therefore, it may be said that the industry is not organized, but that wage arrangements are made between the individual employers and their employees, subject at all times to competitive conditions in the industry and cost of living. The cost of living has been steadily declining since 1922, so

[1] Figures for Mine, Mill, and Smelter Workers Union are taken from *Growth of American Trade Unions 1880–1923*, by Dr. Leo Wolman, National Bureau of Economic Research, 1924, pp. 110–111.

[2] *Ibid.*, pp. 110–111.

that real wages have continued to increase. Present labor conditions in the industry seem to be entirely satisfactory, since the cost of living is declining and wages are not being reduced accordingly. The wage rates in the lead mining and smelting industry seem to be considerably above the rates paid in other mining industries. The Bureau of Labor Statistics made a survey of wages and hours of labor in the principal metalliferous mines in the United States during the summer of 1924.[1] The study included mines producing iron, copper, lead, zinc, gold, and silver, and some of the minor metals as well. This study shows that the average earnings per hour in the Western mixed-ore district, which includes lead and zinc, as well as some of the other metals, was 59.9¢ per hour. The maximum of 69.3¢ per hour was paid in the State of Idaho, which is the third largest lead-producing state in the Union. The average earnings per hour paid in the lead districts of Southeastern Missouri and the Joplin or Tri-State district, is 55.2¢ per hour, the Michigan copper district 49.8¢ per hour, and the Alabama iron district only 39.3¢ per hour. The average earnings per hour of the entire group is 55.9¢. The total number of wage workers covered amounts to 126,958, so that these averages may be taken as indicative of representative conditions in the mining industries.

Financial Organization. The mining industry is of such a nature that the number of employees is small (as measured by other industries) compared to the capital invested. The more important factors are the capital invested in mining and smelting equipment and transportation facilities. To yield a profit, the business must be conducted on a large scale, requiring a considerable amount of capital. It is for this reason that the mining industry was the first to take on the present form of large-scale industrial organization.

Transportation is the most important single factor in getting the ore from the body of the mine to the surface, then to the smelting plant, and finally to the center of consumption. While the veins are still rich and lie near the surface, the transportation problem is not of supreme importance. At this stage mining may be done on a small scale. But as countries grow older and the rich mines near the surface become exhausted, the increased value

[1] *Wages and Hours of Labor in Metalliferous Mines*, Bulletin No. 394 of the U. S. Bureau of Labor Statistics, 1924.

of the product makes it profitable to mine poorer grades of ore. Deeper shafts and poorer grade ore require more underground transportation which involves a larger investment. This is one of the main reasons for the trend toward greater concentration of financial organization in the mining and smelting industries. According to the figures of the Bureau of the Census, there were thirty-nine establishments[1] in the lead smelting and refining industry in 1899; in 1909, twenty-eight; in 1919, twenty-five; in 1921, twenty-three; and in 1923, only twenty. To some extent the decrease is accounted for by the shutting down of the inefficient smelting plants resulting from the various consolidations which took place in the industry in 1900 and in subsequent years.

The end of the Civil War in 1864 marked the beginning of the lead mining and smelting industry in the United States on a large scale. On April 15, 1864, the State of Missouri enacted a statute entitled "An Act Relative to Incorporation for Manufacture and Other Purposes."

The St. Joseph Lead Company was the first mining company to take advantage of this act and formed a corporation with a capital stock of one million dollars. Its steady growth has been financed mainly from its own operations and although it has, from time to time, absorbed other mining properties such as that belonging to Fermin DesLoge in Missouri in the '70s and that belonging to the Doe Run Lead Company in 1914, it has continued to retain its own identity and management from the time of its incorporation. In the sixty-two years of its existence, it has had only three presidents, Mr. Clinton H. Crane, the present president, having assumed this office in 1914. The most rapid and remarkable progress of the company has been made during his administration. It now has a capital stock with a par value of

[1] The term "establishment" signifies a single plant or factory. "In some cases, however, it refers to two or more plants operated under a common ownership and having a single set of books of account. Separate reports are required for plants under a common ownership but located in different municipalities having 10,000 inhabitants or more; but, if located in the same state and in places of smaller size, a number of plants engaged in the same industry and under one ownership may constitute a single establishment for census purposes." *Biennial Census of Manufactures, 1923*, page 5. This definition of establishment does not make the figures entirely clear, but it is safe to conclude that the number of smelters in the United States has decreased considerably.

$20,000,000 and a market value of nearly $80,000,000. The lead content of the concentrates produced by this company in 1926 was 160,907 tons, but " the smelter production available for sale from the company's own ores was 152,766 tons. Including the lead purchased from the Bunker Hill and Sullivan Mining and Concentrating Company, the sales of pig lead for the year amounted to 204,089 tons " or approximately thirty per cent of the total production in the United States. Fermin DesLoge has been closely associated with the St. Joseph Lead Company and has in many ways played a leading part in the development of lead properties in the State of Missouri. In the seventies, he sold his original property to the St. Joseph Lead Company, but later on, bought some additional property upon which he discovered the existence of lead-bearing ore. In 1893, he organized the DesLoge Consolidated Lead Company which has for the last five years averaged an annual production of about fifteen thousand tons of merchantable pig lead.

In the west the leading lead-mining company is the Bunker Hill and Sullivan Mining and Concentrating Company organized in 1887 under the laws of the State of Oregon, but transferred to Delaware in 1924. According to a statement of an officer of this company,[1] " the output of its mines was shipped to various custom smelters until 1898 when the Bunker Hill and Sullivan Company joined the Alaska Treadwell group and others in our purchase of the smelter at Tacoma, Washington. The Tacoma smelter was sold to the Guggenheim interests in 1905. As a condition of the sale, the American Smelting and Refining Company secured a twenty-five year contract for the treatment of such Bunker Hill production as assayed between thirty and seventy-five per cent lead, with a proviso that the contract be revised at intervals to meet whatever competition might dictate. With the tightening of the American Smelting and Refining Company's smelting control, disputes arose over the existing contract, which led to the building of a smelter of its own by the Bunker Hill Company on its property near Kellogg, Idaho. This plant began operations in 1917. Litigation with the American Smelting and Refining Company over the building of this smelter was compromised in 1918 by dividing the Bunker Hill and Sullivan Company production, one half to go

[1] Letter to the writer, dated Feb. 21, 1927 from Mr. Fred W. Van Meter, Asst. Secretary, Bunker Hill and Sullivan Mining and Concentrating Company.

to the Bunker Hill smelter and the other half to the American Smelting and Refining Company's smelters for the remaining twelve years of the original twenty-five-year contract at improved terms." Although the lead production from its own mines amounted to only 37,870 tons in 1926, its smelter production, which includes custom smelting done for other mining companies, was almost twice as large, reaching the figure of 65,545 tons.

The Hecla Mining Company, which has its main office in Wallace, Idaho, was organized in the State of Washington in 1898 and has since operated mines located in Idaho. The lead content of its production in 1926 amounted to approximately thirty thousand tons.

In addition there were many small mines operating in the '90s which were consolidated into the Utah-Apex Mining Company and incorporated under the laws of the State of Maine in 1902. It was not until 1915, however, that this company became a large producer. In 1926, its production amounted to approximately 17,500 short tons of lead. Its lead ore is sent to the American Smelting and Refining Company and the International Smelting Company for smelting. There are many other companies, the individual production of which is not large, but which, when taken in the aggregate, form an important addition to the total lead production of the country. For example, the Bingham Mines, whose lead production in 1926 amounted to about 7500 tons, Chief Consolidated, with a production in 1926 of 15,783 tons, Park Utah Consolidated, with 20,279 tons, Silver King Coalition, 16,956 tons, Tintec Standard, 23,764 tons, Butte and Superior, 4411 tons, and Utah Delaware with 15,931 tons. These seven companies accounted for a production in 1926 of 104,624 tons.

The Pennsylvania Smelting Company, whose works are at Carnegie, Pa., is primarily a smelter of secondary metals, but has some production of pig lead. This is true of other secondary smelters, such as the Federated Metals Corporation and the Balbach Smelting and Refining Company.

There are some companies such as the Anaconda Copper Company, the National Lead Company, the Phelps Dodge Corporation, American Metal Company, and the Eagle Picher Lead Company which, while not classed as lead-mining companies, nevertheless produce a considerable amount of lead. The Anaconda Company

has two subsidiaries which produce lead, the International Smelting Company at International, Utah, and the International Lead Refining Company at East Chicago, Indiana. In 1926, the smelting plant at Utah produced approximately 7500 tons of lead, whereas the refining plant at Indiana treated 83,000 tons of lead bullion, from which were produced about 73,000 tons of common lead, 4000 tons of antimonial lead, and the balance in gold and silver. Copper is also the primary interest of the Phelps Dodge Corporation. Its annual production of lead is only about two or three thousand tons.

Although the history of the Eagle Picher Lead Company extends back to 1843, when Wood and Sons entered the business of manufacturing white lead, colors, etc., in Cincinnati, it was not until 1913 that it entered the field as a lead producer. In 1916, the Picher Lead Company was merged with the Eagle White Lead Company under the name of the Eagle-Picher Lead Company and in recent years has gone more extensively into the mining business. Although the lead content of its production in 1926 was only 10,191 tons, the quantity smelted and refined at its various plants amounted to 79,545 tons. The difference is made up by custom smelting done on a contract basis for other mining companies, which has become an important part of this company's business.

The American Metal Company, Ltd., was incorporated in 1887 in the State of New York with a capital stock of two thousand shares of a par value of $100 each, and for many years did business on a comparatively small scale. In recent years, it has, through various combinations and through its general policy of expansion all over the world, developed into one of the most influential factors in the non-ferrous metal industry in the world. The company's principal lead-mining, smelting, and refining operations are conducted in Mexico through its subsidiary the Compania Minera de Penoles, S. A. The amount of refined lead produced in 1926 was 84,815 tons. The range of its business includes the mining, smelting, and refining of gold, silver, copper, zinc, and lead ores, and the selling of gold, silver, copper, lead, zinc, and tin.

Upon the incorporation of the National Lead Company in 1891 three smelting and refining plants were taken over, two belonging to the old St. Louis Smelting and Refining Company, which had been incorporated in 1871, and the third belonging to the Rio Grande

Smelting Company located in New Mexico. All of the smelting and refining plants were closed down at the time of the panic in 1893. In 1897 and 1898 the St. Louis Smelting and Refining Company purchased some mineral land in St. Francois County, Missouri. These properties were developed and brought into operation in the latter part of 1900. In 1916 further properties were purchased in the same district. In 1903 the company purchased some land near Collinsville, Illinois, and constructed a smelting and refining plant which has been operating ever since. Although its mine production approximates 25,000 tons a year, this is but a small figure when compared to the requirements of the parent company. Originally engaged mainly in the production of white lead, the company has extended its activities to meet the demands of industrial progress in the twentieth century. This has been especially notable under the administration of Edward J. Cornish, its president since 1916. Such a policy has called for greater diversification of manufacture and the formation of subsidiary companies in allied fields. The increased demands for alloys of lead with tin and antimony have made greater supplies of lead necessary, so that at the present time consumers of manufactured lead products in the United States receive about a third of their requirements through the National Lead Company.

The above account records a brief history of the important lead-mining companies, but does not touch upon the activities of the many small smelting companies which were organized in the '80s and '90s. Competition was very keen among the lead smelters in the '90s. The depression of 1893 caused the closing of many of the plants, and those able to continue operation did not operate on a profitable basis. As a result, an association of smelters was formed in 1897 in the hope that it would lead to combination among the various plants. However, due to the inability of the smelters to agree upon values, the actual combination did not take place until March, 1899, when the American Smelting and Refining Company was organized with a capital stock of sixty-five million dollars par value, half in preferred and half in common stock. With few exceptions, such as the Guggenheim Smelting Company, the Balbach Smelting and Refining Company (now operated by the American Metal Company), the St. Louis Smelting and Refining Company (belonging to the National Lead Company), and the Selby Smelting and Lead Company (later acquired by

the American Smelting and Refining Company), the American Smelting and Refining Company included all of the existing smelters in the United States and practically controlled the buying market for lead ore. As was customary in the various consolidations in that period, many of the individuals who sold out to the American Smelting and Refining Company took payment in the securities of the new company and became actively associated with it. However, the Guggenheim interests, which had remained independent, were still a menace to the American Smelting and Refining Company. In 1901, a consolidation with the Guggenheim interests was finally effected. "The Capital stock of the American Smelting and Refining Company was increased to $100,000,000.00, and $45,200,000.00 half in common and half in preferred shares (worth about $36,000,000.00 on quotations of January, 1901) were given to the Guggenheim interests in payment for their smelteries at Monterey and Aguascalientes, Mexico, the smeltery at Pueblo, Colorado, a smeltery in Chile, the refinery at Perth Amboy, together with the working capital and cash assets of the firm and $6,066,667.00 in cash additional. There was severe criticism of the high price paid to the Guggenheims, who were considered to be capturing the American Smelting and Refining Company, although nominally they were being absorbed. Several of the brothers entered the directorate of the company, wherein they soon became paramount . . . Although at the time of their consolidation with the American Smelting and Refining Company, the Guggenheims were thought to be receiving an exorbitant price, it soon came to be recognized that they were making the success of the enlarged company." [1]

The American Smelting and Refining Company was well on the way towards the control of the lead mining and smelting in the United States. It now set out to gain control of the lead manufacturing business, so as to have an outlet for its raw product. In 1903, it organized the United Lead Company, which was a consolidation of a great many metal manufacturing plants and several shot towers, and then proceeded to erect a white lead plant in Perth Amboy to compete with the National Lead Company. In 1906 the National Lead Company was persuaded to buy the United Lead Company, and has since retained it as a subsidiary company. Shortly thereafter, the Guggenheims retired from the Board of

[1] W. R. Ingalls, *Lead and Zinc in the United States*, p. 242.

Directors of the National Lead Company, and since then, neither the American Smelting and Refining Company nor the Guggenheim interests have had any connection with the National Lead Company.

In 1905 the American Smelting and Refining Company increased its interests in the lead mining and smelting business by the purchase of the Federal Mining and Smelting Company, a company resulting from a consolidation of many of the important mining companies in the Cœur d'Alene region in Idaho.

Practically every phase of the non-ferrous metal industry is included in the business of the American Smelting and Refining Company. It is one of the largest smelters of copper, lead, and silver in the world and produces gold and spelter and many by-products on a large scale. Its assets exceed $200,000,000.00. The lead production of its various smelters in 1926 amounted to 467,607 tons, considerably more than half of the total pig lead production in the United States. For a short time after its organization, the American Smelting and Refining Company had a fairly complete control of lead smelting in the United States, but competition soon arose, both through the expansion of the independent companies, such as the St. Joseph Lead Company, the Bunker Hill and Sullivan Mining and Concentrating Company, and through the formation of new competitive consolidations.

In 1905, the United States Smelting, Refining and Mining Company was organized to take over several independent plants then in existence, with the intention of competing with the American Smelting and Refining Company. The range of the business of the United States Smelting Company is about as wide as that of the American Smelting and Refining Company, but is conducted on a smaller scale. Its assets are only about $76,000,000.00 as compared with approximately $230,000,000.00 for the American Smelting and Refining Company. The United States Smelting Company produces coal, gold, silver, copper, and lead on a considerable scale. Its lead production at the Bingham Mines in 1926 amounted to about 15,000 tons, but the amount of its smelter production exceeded 64,000 tons, because of the considerable amount of custom smelting done for other mining companies.

The lead industry is one of the least integrated of the large industries in the United States. Large lead-mining companies, such as St. Joseph Lead Company, the Bunker Hill and Sullivan Mining and Concentrating Company, and several of the smaller

ones do not go further than mining and smelting. The large smelting companies, such as the American Smelting and Refining Company, do not go in for the manufacture of lead products. It is only some of the large manufacturing companies, such as the National Lead Company and the Eagle-Picher Lead Company, whose main interest lies in the manufacture of white lead and other lead products, which form a complete integrated unit. They not only mine, smelt, and refine their own lead, but use it in their own processes of manufacture and sell it to jobbers and wholesalers as a finished product. It should be pointed out, however, that the amount of lead mined by these companies is only a very small portion of their total consumption.

Considered as a whole, the industry, as it is organized in the United States at the present time, may be divided into three groups: The mining group, which contains a few predominating companies, the smelting group, the outstanding factor of which is the American Smelting and Refining Company, and the manufacturing group. The lead industry contains no such examples of integration as the New Jersey Zinc Company in the zinc field, the Anaconda Copper Company in copper, or the United States Steel Corporation in the iron and steel industry.

World Production of Pig Lead. In the year 1926 the pig-lead production of the world reached 1,758,558 short tons, a figure which set a record for the world annual production, both in quantity and value. The production for the year 1927 is estimated at 1,829,100 short tons, over 70,000 tons' increase over the previous maximum annual production. The United States is the leading producer as well as the leading consumer of lead, and usually produces approximately enough to supply its own needs, the margin, if any is necessary, being imported from Mexico. For the ten years from 1917 to 1926 it produced 41.88% of the world's total, whereas its consumption amounted to 44.88% of the total lead consumed. The British Empire produces 21.50% of the world's lead, the supply coming mainly from Canada, Australia, and Rhodesia. Mexico is third in production with 220,879 short tons or 12.56% of the world's total. Spain, Germany, Belgium, and France follow in order. The exact figures are contained in Table I and Graph I.[1]

[1] The basic figures for the above compilation and arrangement are taken from the yearbooks of the American Bureau of Metal Statistics.

TABLE I

WORLD'S PIG LEAD PRODUCTION 1926 (SHORT TONS)

	1926	Per Cent	10-Year Average 1917–1926 Inclusive	Per Cent
United States	696,000	39.58	541,969	41.88
British Empire	378,717	21.54	240,282	18.57
Mexico	220,879	12.56	131,723	10.18
Spain	162,470	9.24	159,345	12.31
Germany (excluding Upper Silesia)	84,034	4.78	58,058	4.49
Belgium	68,080	3.87	41,193	3.18
Other Countries	56,642	3.22	45,942	3.56
France and Tunis	42,004	2.38	34,242	2.64
Italy	25,534	1.45	19,533	1.51
Upper Silesia	24,198	1.38	21,775	1.68
	1,758,558	100.00	1,294,062	100.00

The high prevailing prices of lead during the year 1926 were a stimulus to subsequent increased production. There were, however, other factors such as the technological advances in the mining and smelting industry. Improvements such as the flotation process have made the use of low-grade complex ore commercially profitable and, to that extent, have brought in a supply of ore which had previously not been available for commercial purposes.

World Consumption of Pig Lead. In the year 1926, the record world's consumption of 1,690,818 short tons of lead was set. While the 1927 consumption was slightly under this maximum figure, it has, nevertheless, exceeded all years previous to 1926. An increase in the world's consumption of lead in recent years, especially in the United States, has followed the rapid development of the automobile industry and the more extensive use of underground cables by the telephone and telegraph companies. Table II shows the world's consumption of pig lead by countries for the year 1926 compared with the ten-year average 1917 to 1926.[1]

In 1926 the United States consumed somewhat more than it produced. The British Empire, on the other hand, consumed only 19.63%, whereas its production was 21.54% of the total. France,

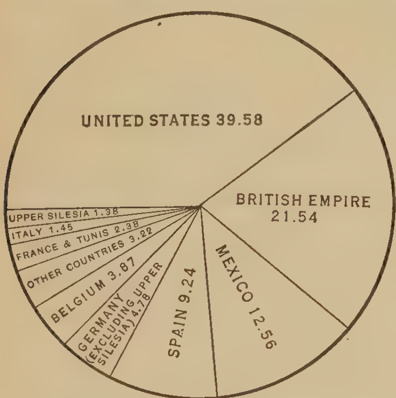
[1] The basic figures for this compilation and arrangement are taken from the yearbooks of the American Bureau of Metal Statistics.

TABLE II

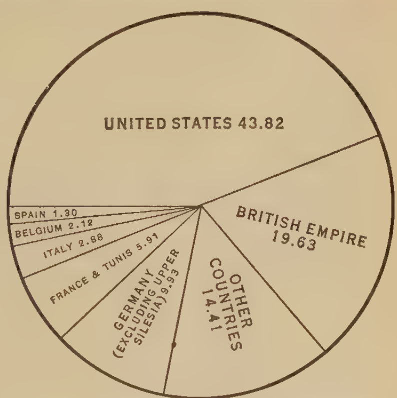
WORLD'S CONSUMPTION OF PIG LEAD 1926 (SHORT TONS)

	1926	Per Cent	10-Year Average 1917–1926 Inclusive	Per Cent
United States	740,856	43.82	572,719	44.88
British Empire	331,903	19.63	264,029	20.68
Mexico				
Spain	22,046	1.30	18,188	1.43
Germany (excluding Upper Silesia)	167,880	9.93	118,299	9.27
Belgium	35,825	2.12	26,488	2.08
Other Countries	243,607	14.41	156,670	12.27
France and Tunis	99,979	5.91	86,024	6.74
Italy	48,722	2.88	33,808	2.65
Upper Silesia				
	1,690,818	100.00	1,276,225	100.00

Germany, and Italy all consumed more than they produced. With the exception of such countries as Mexico and Spain, which export practically all of the lead they produce, the correspondence between



Lead production, 1926. Percentages by countries, in short tons.



Lead consumption, 1926. Percentages by countries, in short tons.

production and consumption of lead by countries is unusually close. In this respect lead differs from such products as tin, which is consumed almost entirely in countries other than those which produce it.

Conclusion. The quantity of metals consumed is a fairly good index of the state of industrial development of a country.

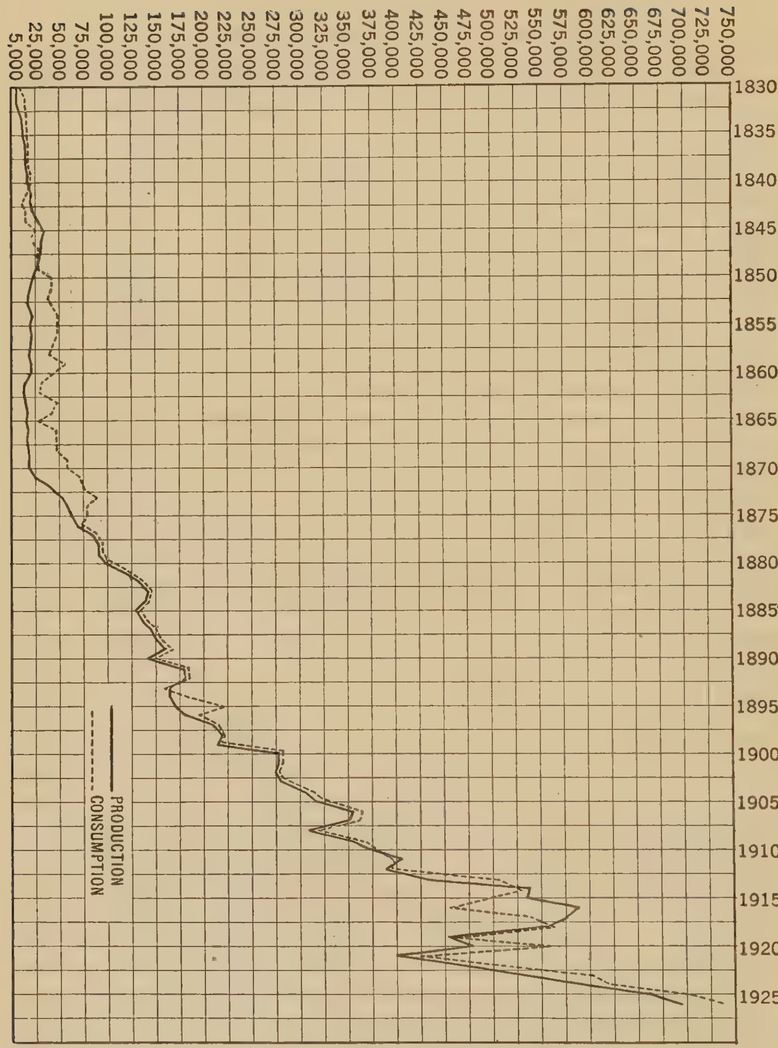


CHART III. — Production and consumption of pig lead in the United States, 1830–1926, inclusive (1830–1907 taken from *Lead and Zinc in the United States*, Ingalls, 1908, McGraw-Hill; 1908–1913 from *Mineral Resources of the United States;* 1914–1926 from *Year Book of American Bureau of Metal Statistics, 1925–1926*).

Chart III shows the production and consumption of pig lead in the United States by years from 1830 to 1926 and reflects the tremendous growth in industry in the country during this period.

Chart III indicates that in the United States production has grown at a faster rate than consumption. Up to about 1875, a considerable amount of lead was imported for domestic use. With the increased production in the latter part of the nineteenth century, the import of lead decreased to a negligible quantity. In the first quarter of the twentieth century, production of lead has exceeded that of the entire period 1830–1900.

The 1927 consumption for pig lead has exceeded 1926, although the exact figure is not as yet definitely established. In 1926 the consumption of pig lead in the United States amounted to about 750,000 short tons as compared with 276,000 consumed in 1900, an increase of about one hundred and fifty per cent. The increase in the previous twenty-five years from 1875 to 1900 was smaller in absolute quantities, but somewhat larger in relative percentages. The consumption in 1875 amounted to about 92,000 tons and in 1900 to about 276,000, an increase of 164,000 tons, or about one hundred and seventy-five per cent of the 1875 figure.

Production increased at a faster rate than consumption up to about 1880, but since then, the rate of increase has been about the same for both production and consumption of pig lead. The rate of increase has been considerably larger than the growth of population, or than the increase in the general index of production. Present indications are that the next few years will witness continued large production of pig lead in the United States, with an accompanying increase in consumption, but at somewhat lower price levels than have existed in the previous two or three years.

CHAPTER XI

THE BLUE LEAD AND MIXED METALS INDUSTRY

By J. R. Wettstein [1]

By the term Blue Lead, the industry understands all products of lead which undergo no chemical change in manufacture as distinguished from White Lead or the Oxides of Lead. The industry may properly be divided into two major divisions: (1) Lead Pipe and Sheet Lead, and (2) Lead Shot. The former embraces a varied line of other products which by themselves would scarcely rise to the dignity of having them classified as a separate industry, yet in the aggregate they form a considerable volume.

The total business in dollars of Lead Pipe, Sheet Lead, Shot, and White Metals, while not to be compared in magnitude with many other lines, is nevertheless of sufficient volume to command an important place in the industries of the United States. A fair and conservative estimate of the business done in these lines in 1926, excluding metals used in encasing cables, will easily reach the sum of $80,000,000, based on prices ruling for raw materials during that year.

Lead Pipe and Sheet Lead. The early history of this industry in this country is shrouded in the obscurity of a slowly growing demand brought on by increasing population and the advance of modern civilization. It is certain that the pioneers and early settlers had no need for either Lead Pipe or Sheet Lead, and it cannot be conceived that a demand developed until the nineteenth century was well on its way. There was probably a moderate call for Lead Pipe made from Sheet Lead with the seam burned, as was the practice of the old Romans. The Sheet Lead thus made was probably cast on a bed of sand, and perhaps slight effort was made to roll it to smooth out gross imperfections. At any rate there is no record of machinery until 1829, when the first meeting

[1] President, United Lead Company, New York.

of Directors of the Boston Lead Company was held. This was on April 27, and William B. Swett was elected president. The company was incorporated by act of the legislature of the Commonwealth of Massachusetts on March 2, 1829, and its object was "the conducting and carrying on the various processes of manufacturing articles from lead." Its capital was not to exceed \$250,000, and its real estate holdings were limited by the act of incorporation to a value of not to exceed \$50,000.

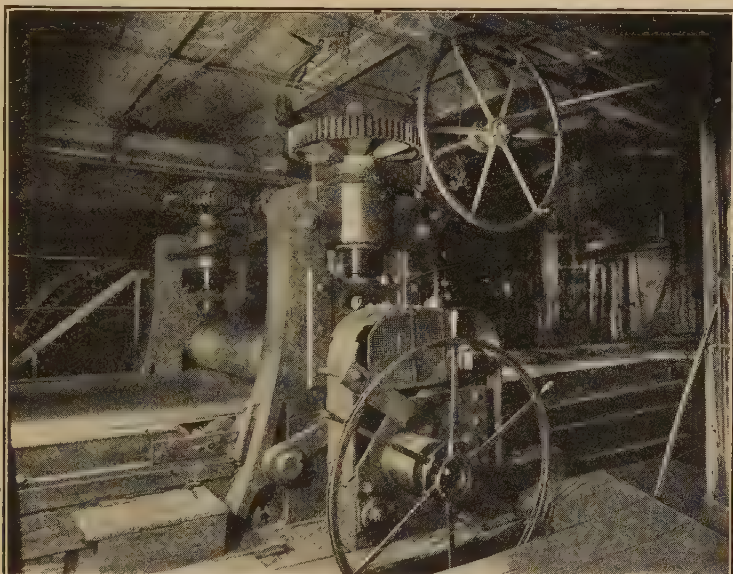


FIG. 1.—The first steam-driven Sheet Lead Mill in the United States, installed in 1840 at the Tatham Brothers plant in Philadelphia, still in operation.

Though the demand for Lead Pipe and Sheet Lead must have been very small in these early days, it is conceivable that Lead Pipe was made in a crude way by plumbers or mechanics in the various settlements and cities as incidental to their work, and before the advent of the hydraulic press. The old Roman method of fashioning pipe out of Sheet Lead was probably employed, though an intermediate process between that and the hydraulic press was the casting of Lead Pipe in short lengths which were then drawn through cores and dies to lengths of from 10 to 18 feet. The hydraulic press was an English invention and was probably brought to

this country late in the thirties or early in the forties as the demand for pipe became more persistent and general. At any rate, in 1840 the firm of Tatham and Bros. of Philadelphia was organized, composed of George N. Tatham, Benjamin Tatham, and Henry B. Tatham, and the same year this firm imported an hydraulic press bought from Hanson Brothers in England, patentees of the press, patents taken out in Huddersfield, County of York, August 1, 1837. The Tatham firm in Philadelphia was given the exclusive patent rights for the United States. This press is still (1927) a part of the equipment of the Tatham Brothers plant in Philadelphia, now owned by the United Lead Company. It is probable, too, that the Sheet Lead Mill still in operation at the Tatham plant in Philadelphia was imported about the same time. A plate on the mill reads, "Francis, Smith and Hawkes, Manufacturers of Steam Engines, Sugar Mills, Sugar Pans, etc., Eagle Foundry, Birmingham."

The Boston Lead Company, in addition to manufacturing Lead Pipe and Sheet Lead, was also engaged in manufacturing White Lead, Red Lead, and Litharge, and early in its career installed a rolling mill for Sheet Lead, purchased under contract dated April 1, 1830, from the Mill Dam Foundry. On April 20, 1852, this Company purchased the Norfolk Lead Company of Roxbury, also manufacturers of White Lead, Red Lead, Litharge, Chrome Yellow, Sheet Lead, etc., though little is known of the activities of this Company. It may have been purchased in its infancy, as was often the practice in later years to stifle competition. The Boston Lead Company failed in 1878, and in 1879 the Boston Lead Manufacturing Company was incorporated as a reorganization. In 1879 the Chadwick Lead Works was founded by J. H. Chadwick, who for many years was part owner and agent of the Boston Lead Company, and in 1901 the Chadwick Lead Works and the Boston Lead Company consolidated as the Chadwick-Boston Lead Company, to be absorbed in 1903 by the United Lead Company.

In 1841 Tatham Brothers of Philadelphia, augmented by William B. and Charles B. Tatham, established another plant located at 249 Water Street in New York City, and the manufacture of Lead Pipe by hydraulic pressure and the rolling of Sheet Lead by steam-driven mill was inaugurated in New York City. Shortly thereafter the firm of Lober and LeRoy was founded by Jacob LeRoy together with his son Thomas Otis LeRoy. The original plant was on the lower West Side of New York City on

Liberty Street between Broadway and the North River, but after a few years was moved to 261 Water Street because the East Side gave promise of earlier development by reason of the growth of Brooklyn. The same location and the original buildings are now in use as a warehouse of the United Lead Company. The original mortgage on the property was satisfied in 1924, having remained undisturbed for something like seventy years, — somewhat of a record in the life of a mortgage. Lober and LeRoy were suc-

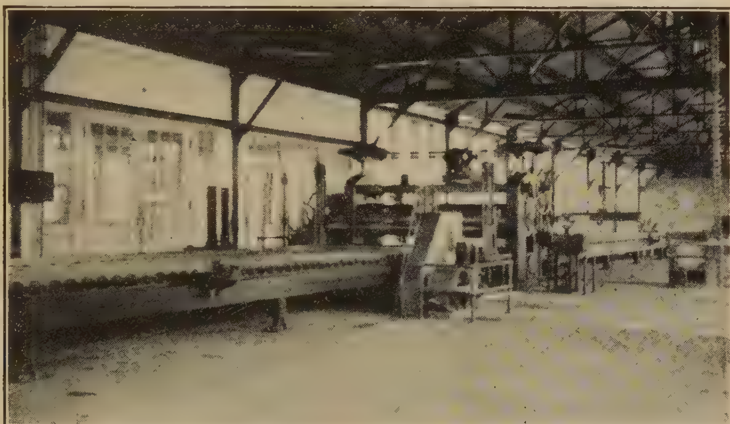


FIG. 2. — A modern lead rolling mill electrically driven. Slabs of lead are cast weighing five to seven tons and these are passed through the mill and rolled into sheets to the required dimensions.

ceeded by Thomas Otis LeRoy and Company, composed of Thomas Otis LeRoy and David Smith. Edward A. LeRoy, who was prominent in the industry in the last half of the nineteenth century, was the son of Thomas Otis LeRoy and was identified with the company until it sold out to the American Shot and Lead Company in 1890. Two years later, O. D. Delano became Manager of the plant and at this writing (1927) is Manager Emeritus of the Blue Lead plant of the United Lead Company in Perth Amboy, N. J.

The firm of The Colwells, Shaw and Willard Manufacturing Company was established in Centre Street, New York, later on becoming the Colwell Lead Company, Joseph Colwell being president of the original company. The Hooper family later on became dominant in its affairs, and the close of the nineteenth century found B. Frank Hooper the leading spirit. The company manu-

factured Lead Pipe, Sheet Lead, and Shot. In 1910 it sold its lead business to the United Lead Company and soon thereafter, as a jobbing house, it went into bankruptcy, to be reorganized and absorbed by the present Pierce, Butler and Pierce Manufacturing Corporation, one of the prominent concerns in radiation and plumbing supplies.

Minor concerns of no national importance sprang into being in the various eastern centers, few of which could withstand the fierce competition for any length of time, yet the firms of F. N. DuBoise and Co. and Marks Lissberger and Co. may be mentioned as still in business in their respective lines. To F. N. DuBoise must be given the credit of inventing the modern hydraulic lead-trap press, and the patent monopoly was enjoyed by that firm during the life of the patent.[1]

In Baltimore there was established in 1872 by John McPhail a Lead-Pipe and Sheet-Lead manufacturing plant for account of the James Robertson Mfg. Company of Montreal. This plant gained an enviable reputation for manufacturing sheet lead for the chemical trade, and John McPhail, who died in 1926, and William A. Price, whose death occurred in 1923, of the Gibson and Price Company, shared alike in the reputation of a long and influential career in this particular industry covering a period of half a century. The Gibson and Price plant in Cleveland and the Robertson plant in Baltimore are owned and operated by the United Lead Company. The Cleveland mill was originally in operation on Staten Island, New York, and was brought to Cleveland in 1875. The present Gibson and Price plant at Cleveland was originally founded in Cincinnati by Thomas and William Gibson about 1872 under the name of the Gibson Lead Works. The Cincinnati mill was sold to John D. Abraham and the business was continued as the Cincinnati Lead Pipe and Sheet Lead Works, later on to be acquired by Clark and Hawley. The lead rolls were probably scrapped and the Lead-Pipe press was acquired by the American Shot and Lead Company, the firm of Clark and Hawley finally becoming the present Cincinnati branch of the Crane Company, known as the Crane Hawley Company.

The Cleveland plant was founded by Samuel Gibson, who had been superintendent of the Gibson Lead Works, though no relative of the principals, in 1874, together with W. J. Roberts, as the firm of Gibson and Roberts, William A. Price coming into partnership

[1] F. N. DuBoise and Co. passed out of existence late in 1927.

in 1875. In 1879 W. J. Roberts established a Lead-Pipe factory in Syracuse, N. Y., which later on was acquired by Pierce, Butler and Pierce, and in about 1912 the Lead-Pipe machinery was purchased by the United Lead Company, overhauled, and installed in some of its numerous plants.

The Charleston Lead Works of Charleston, South Carolina, was established in the late nineties and is still operating as a lead-pipe and sheet-lead plant, and the Andrews Lead Company of Long Island City is the last to enter the field in the East, the plant being erected in 1922. The Cornell Lead Company of Buffalo, a constit-

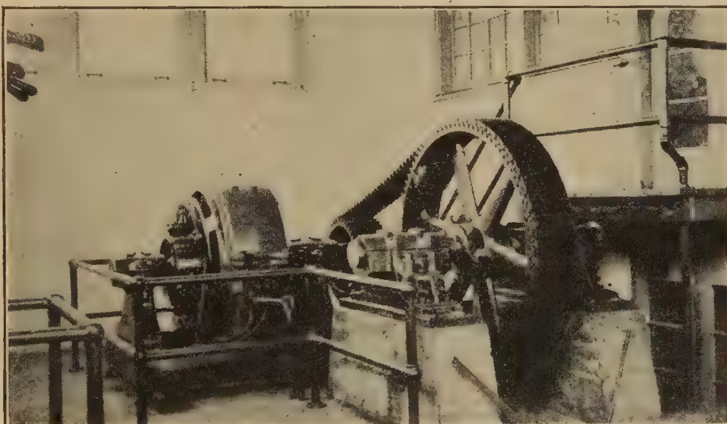


FIG. 3.—Electric motor (75 H. P.), showing 10″ Morse chain, driving mill illustrated in Figure 2.

uent branch of the National Lead Company, installed lead-pipe machinery in the last half of the nineteenth century which is still being operated, as also are pipe presses owned by the Rochester Lead Works and Charles Millar and Company of Utica, N. Y. There is record of a sheet-lead mill operated at Providence, Rhode Island, but of short duration, which was acquired by Marks Lissberger and Co. of New York. The mill, however, was never overhauled and is probably today what might be termed junk.

It was natural that with the unfolding of the West the Lead-Pipe and Sheet-Lead business should be drawn into its growth. In Pittsburgh, Bailey Farrell and Company, manufacturers of Lead Pipe, Sheet Lead and Shot, and the W. G. Price Company, manufacturers of Lead Pipe and Shot, were some of the earlier ones, the machinery of Bailey Farrell and Co. (excepting shot) finally

finding a permanent place in the equipment of the National Lead Company of Pittsburgh. In Detroit, the forerunner of the present Detroit Lead Pipe and Sheet Lead Works was Mr. S. Ferguson. In Cincinnati a rolling mill was operated in the eighties by Hugh McCullom and Son, who had been in the plumbing business for many years, but the mill was not in operation long and was purchased by E. W. Blatchford and Co. in Chicago. The firm of Merrie Verhage and Co. in Cincinnati was at one time quite prominent in Lead Pipe and its Shot business was conducted as the Cincinnati Shot Works. Hugh Merrie, the principal of the firm, was also interested in and controlled the Continental Shot and Lead Works in Kansas City, manufacturers of both shot and lead pipe. This business was absorbed in 1890 by the American Shot and Lead Company. The Kentucky Lead and Oil Company, another constituent plant of the National Lead Company, manufactured Lead Pipe in the early eighties, Mr. L. Leonard being president, and the present plant of the National Lead Company in Cincinnati had among its early equipment a Lead-Pipe Press. The Eagle White Lead Company, now the Eagle Picher Company, installed Lead-Pipe presses in the first decade of this century which are still in operation, as are also presses owned by this company at Joplin, Mo.

St. Louis, being the largest city in the West in the middle of the century, began early to manufacture Lead Pipe. It was in 1848 that E. W. Blatchford in partnership with a Mr. Collins engaged in its manufacture, but six years later E. W. Blatchford moved to Chicago and began the manufacture of Lead Pipe at the corner of Clinton Street and what was then known as the head of the Milwaukee Plank Road, — now Milwaukee Avenue. Part of the buildings are still used as a warehouse of E. W. Blatchford and Company, now a branch of the United Lead Company. The Blatchford firm soon became dominant in the entire West as the largest Lead Pipe, Sheet Lead, and Mixed Metal concern, and in due course erected a Shot Tower which was razed in the late nineties. This firm early in its career absorbed the lead-pipe establishment of Marks Lissberger, who later on established himself in Long Island City. Mr. N. H. Blatchford, a brother of E. W. Blatchford, entered the firm in the late sixties, retaining the management of the Blatchford branch in Chicago, until his death in June, 1927.

The Raymond Lead Company, founded by James N. Raymond, who died in 1919 and who had been a salesman for Mr. Ferguson in Detroit, was founded in the late seventies and in time became very prominent. In fact the Blatchford and Raymond concerns dominated the entire West and at times the competition between the two verged on the edge of serious financial strain for one or the other. The Raymond plant at present, re-located by the United Lead Company in the western part of Chicago and greatly enlarged, is probably the finest example in the world of what a modern Blue Lead plant should be, both in point of capacity and efficiency and variety of products manufactured. The Northwestern Linseed Oil Company of Chicago installed presses for Lead Pipe in the eighties. This plant, known as the Lausten Lead Works, was absorbed by the American Shot and Lead Company, and later on by the United Lead Company.

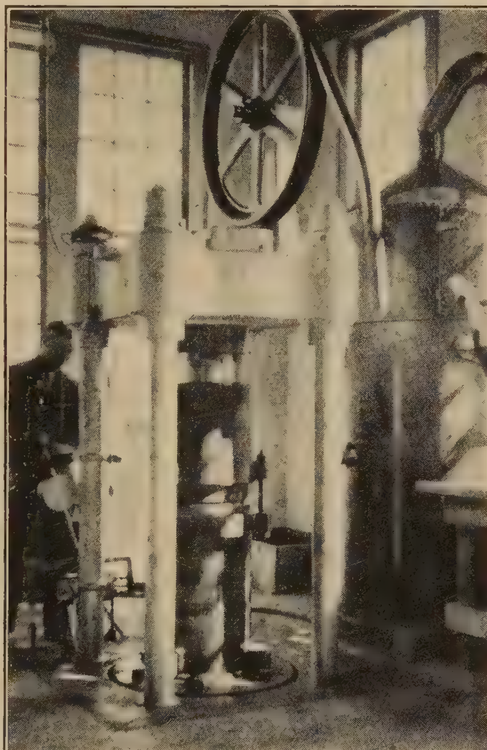


Fig. 4. — A modern Lead-Pipe press.

Among the early Sheet-Lead mills in the West was one operated by the Missouri Lead and Oil Company of St. Louis, one of the constituent plants of the National Lead Company, but in the records of the Western Lead Pipe and Sheet Lead Association we find it was decided to purchase this mill for $30,000. The expense of this purchase was pro-rated among the members of the association and the mill was advertised for sale for a period of six months without finding a purchaser. The Association, which was nothing but

an old-fashioned pool very common in those days, finally decided to break up the mill and to scrap it.

The firms of L. M. Rumsey Manufacturing Company, N. O. Nelson Manufacturing Company, and the Western Brass Company, all of St. Louis, were manufacturers of Lead Pipe, the Rumsey concern also rolling Sheet Lead. The latter company was acquired by the Standard Sanitary Manufacturing Company in 1916, and its equipment, being totally out of date and in bad state of repair, was scrapped. The Western Brass Company failed around the close of the last century and the N. O. Nelson Company is still in business. The Collier White Lead and Oil Company, a constituent of the National Lead Company, entered the business of manufacturing Lead Pipe and Sheet Lead in 1883 and eventually became a considerable factor. They are still active in the business as a branch of the National Lead Company.

The Hoyt Metal Company of St. Louis began rolling Antimonial Sheet Lead about 1900, being the pioneers in this particular field. As a subsidiary of the United Lead Company they are still engaged actively in this line, and in addition are rolling soft lead, britannia metal, music plates, and other highly specialized products.

In the late eighties the Northwestern Shot and Lead Company and the Omaha Lead Pipe Company were operating lead pipe plants in St. Paul and Omaha, the two later combining under the former's title. The Company was largely controlled by E. W. Blatchford and Company of Chicago, and both plants were absorbed in 1890 by the American Shot and Lead Company.

The Pueblo Smelting and Refining Company of Pueblo, Colo., a lead smelter and refinery, was operating a rolling mill in the eighties, but its location did not lend itself to such a project and the mill soon became idle and was sold in the nineties as junk. The Selby Smelting and Lead Company of San Francisco was for many years engaged in manufacturing lead pipe and sheet lead and was dominant on the Pacific Coast. The San Francisco fire of 1906 destroyed the plant, and a modern rolling mill was installed at their smelter at Vallejo Junction, which is still in operation. The pipe presses are located in San Francisco. The plant is now owned by the American Smelting and Refining Company of New York. More recently, some ten or fifteen years ago, a plant for making lead pipe and sheet lead was established in Seattle under the name of the Northwest Lead Company. It is controlled

by the Bunker Hill Mining and Smelting Company and is still in operation.

Modern mills of recent design are operated by the National Lead Company at their Brooklyn plant, by the United Lead Company at Perth Amboy, N. J., where is located the largest Blue Lead manufacturing plant in the world, and by the Georgia Lead Company at Atlanta.

Mention has already been made that in ancient days lead pipe and sheet lead were known and used in water conduction and for baths, but manufacturing was crude and accomplished by hand. There is no reference to machinery in the records of this country until the early part of the nineteenth century, and probably for no other reason than that the demand prior to that period was so limited in volume that there was no need for machinery. From the process of fashioning lead pipe from sheet lead by hand and from the casting of sheet lead on sand or flat surfaces, the first step in advance was the casting of pipe in short lengths to be drawn into longer lengths and various diameters and weights until, as has already been mentioned, the development of the extrusion process by hydraulic pressure, which was undertaken and patented in England. There was a patent issued to one Burr in England in about the year 1820, but this process was far from satisfactory since it is said no pipe could be made by it under $2\frac{1}{2}$ inches in diameter. The Hanson patent, heretofore alluded to, was looked upon as a great improvement, and it was a Hanson press which was brought to Philadelphia in 1840. Crude mills, steam driven and simple in construction, for the rolling of sheet lead were used in Boston at least a decade earlier.

Refinements in extrusion and rolling were undoubtedly developed as demand for the product increased, but they were of such a minor nature as not to be noticeable in the march of time. The fact is, the principles of extrusion and rolling were altered but little, if at all. The capacities of mills and presses were, however, increased from time to time. The modern mill is vastly superior to early ones but chiefly in that it is electrically driven, has a longer rolling table, and is installed in a modern building with ample light, while, curiously enough, the smaller and more cumbersome mill of former days seemed invariably to be installed in the basement of a building with head room barely sufficient to permit the mill men to stand erect in their work. Of the modern lead-pipe press about the same

can be said. It is operated by pumps driven by motor instead of by steam, and the press itself is installed in lighted quarters and so exposed as to make all parts easily accessible. The capacity of the present-day press is much greater than its progenitor. It is much more symmetrical, powerful, and finished, and while the saving in man labor per press is negligible, its increased capacity makes for greater economy of operation. Progress in manufacturing, both in rolling and extrusion, is to be found only in refinement of operation and in the use of electricity in place of steam. The engineering firm of John Robertson Company of Brooklyn manufactured the first hydraulic lead-pipe press in this country some eighty years ago. They and the Elmes Engineering Company of Chicago are responsible for many of the refinements in construction which characterize the modern press.

Shot. It is said that the underlying principle of the modern method of making shot was discovered by accident in England several centuries ago by the upsetting of a pot of molten lead which a plumber was using in the repair of a church steeple. The story goes that the lead splashing out of the pot found its way to the bottom in globular form, which undoubtedly caused the conception of the more modern shot tower. In this country the shot industry antedates the manufacture of lead pipe and sheet lead, probably because a very much larger demand had sprung up for lead bullets and shot in the pursuit of game. The first shot tower in this country was probably erected in Philadelphia in 1808 and was known for many years as the Sparks Tower. It is still standing as a monument to the industry that has since become but a side line in the manufacture of ammunition. This was followed in 1821 by the erection of what was known as the Fifty-third Street Tower in New York City, located at 53rd Street and East River and built by George Yule. In 1828 the Merchant Shot Tower of Baltimore was erected, and this is still standing, recently purchased by the city and preserved by it as a memorial. The Shot Tower in Beekman Street, New York City, owned by Tatham Brothers, was erected in 1858 and was for years a familiar sight to downtown New Yorkers. Another tower in Centre Street near the Tombs, owned by the Colwell Lead Company, was erected later and became a landmark for many years until its demolition in about the year 1910. Another shot-manufacturing plant was located at 261 Water Street, owned by the LeRoy Company, but this was better

known as the "Wind Tower," which employed a new principle in the manufacture of shot to avoid a high tower. The lead was melted in a penthouse on the roof of the four-story building, dropped into a well, and in its descent it met with a cool blast of air which naturally retarded the velocity and permitted it to cool before striking the water. This principle was more successfully used in the erection of some of the larger towers built in the early part of this century. Shot towers sprang up in the West, and the earliest record of shot-making as far West as the Mississippi River was on the banks of the river near what is now the St. Joe Lead Company's smelter. Later on when lead was discovered in the eastern part of Iowa near the river and at Galena, Illinois, similar crude efforts were made to manufacture shot at Dubuque, where the lead was dropped in a mine shaft. Towers were in operation at Pittsburgh, owned by Bailey, Farrell and Company and William G. Price and Company; at Cincinnati by Hugh Merrie, known as the Cincinnati Shot Works, and by E. H. Murdock, known as the Sportsmen Shot Works; at St. Louis the Collier Shot Tower Works and the St. Louis Shot Tower Works, G. W. Chadbourne, one of the outstanding figures of the industry, being president of the latter; at Kansas City the Continental Shot and Lead Works, owned by Hugh Merrie of Cincinnati; at New Orleans, La., the Gulf Shot and Lead Company, of which A. S. Ranlett was the president; at Omaha and St. Paul, known as the Northwestern Shot and Lead Company; and at Chicago the Chicago Shot Tower Works, owned by E. W. Blatchford and Company, and a shot plant owned by the Raymond Lead Company. In later years another shot tower was erected in Omaha by F. B. Lawrence, long prominent in the West as the secretary of pooling organizations in lead pipe, sheet lead, and shot. There was also a shot tower in San Francisco,

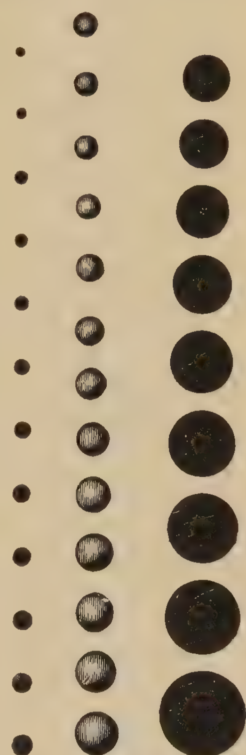


Fig. 5. — Various sizes of lead shot manufactured in the United States.

owned by the Selby Smelting and Lead Company, which was destroyed by fire in 1906 and rebuilt at Vallejo Junction near San Francisco. Another shot tower was at Granite City, Illinois, opposite St. Louis, known as the Markle Shot Tower, and one in Alton, Illinois, owned by the Western Cartridge Company. A very modern tower was erected by the United Lead Company in Perth Amboy, N. J., in 1906 with a capacity the equal of four or five other towers in the eastern district, and more recently the Remington Arms Company and the Winchester Repeating Arms Company erected towers at Bridgeport and New Haven respectively.

The history of the shot business presents a curious picture of the rise and fall of an industry that was once looked upon as important wherever there was a shot tower. Naturally it began in a small way in the East, but in time as the country grew and prospered it spread rapidly and the commodity was handled by wholesale grocers and wholesale hardware houses and large woodenware concerns. The business assumed a volume of some 30,000 tons per annum, which was distributed in these various trade channels in carload lots, the South using about two thirds of the entire production of the country. In the early seventies when breach-loading shot guns were beginning to be manufactured, and, coincident with their introduction, a demand sprang up for shot loaded in brass shells, the growing ammunition concerns of the East, notably the Winchester Repeating Arms Company, the Union Metallic Cartridge Company, and the United States Cartridge Company, were not slow to recognize this demand, and their combined ingenuity soon perfected the paper-shot shell which by its cheapness found almost instant favor.

Late in the eighties it dawned upon the shot manufacturers of the country that a serious inroad was being made upon their business by the rapidly growing use of the breach-loading shot gun and the paper-shot shell, so that, slowly at first but with ever increasing momentum, the shot business of the country gravitated to the East and into the factories of the ammunition companies who were loading their paper-shot shells for distribution to the trade. The shot manufacturers in the late eighties were going through a period of very unprofitable prices, slackening demand, except such as came from the ammunition companies which had to be supplied in ever-increasing volume at diminishing margins, and were finally com-

pelled as a matter of self-protection to consolidate, and this was done in 1890 by the formation of the American Shot and Lead Company, known as the Shot Tower Trust, with headquarters in Chicago. This company included the LeRoy plant in New York, the Merchant Shot Tower in Baltimore, the William G. Price Company and the Bailey, Farrell Company in Pittsburgh, Cincinnati and Sportsmen Shot Works in Cincinnati, Chicago Shot Tower, Chicago, Northwestern Shot and Lead Company in St. Paul and Omaha, Continental Shot and Lead Company of Kansas City, Collier and St. Louis Shot Towers in St. Louis, and the Gulf Shot and Lead Company in New Orleans. The consolidation proved only moderately successful. Its first president was John Farrell of Pittsburgh, soon followed by Alexander Euston of St. Louis, and after ten years it became quite manifest that a larger and more effectual consolidation of lead interests would be necessary to preserve profits. The business of the Western towers had shrunk to the point where their profitable operation was almost impossible; the New York towers were running night and day to supply the ever increasing demands of the ammunition companies on constantly diminishing margins; and some of the Western towers shipped shot into New Haven and Bridgeport at prices that must have netted them positive and heavy losses if it had not been for the demoralization in freight rates which enabled them at times to secure rates as low as the rate on pig lead. It was not uncommon to find freight quoted as low as 12 cents per 100 lbs. on shot from St. Louis to New Haven. With this gloomy prospect the dominant spirits in the industry, notably Alexander Euston and N. O. Nelson of St. Louis, and Theodore Ahrens of Louisville, plumbing supplies manufacturer, conceived the idea of effecting a consolidation that would embrace not only shot but lead pipe, sheet lead, all kinds of plumbing supplies, including pottery, iron soil pipe, in fact all products of lead and plumbing supplies except white lead and the oxides of lead. A prominent New York banking concern was enlisted to underwrite the project, and it was to be called the American Plumbing Supply and Lead Company. Offices were rented in the new American Surety Building, 100 Broadway, and the day and hour was set upon which the money to finance the enterprise was to be paid over. At the crucial moment, owing to some Wall Street disturbance though it was the height of the era of consolidations, — the Flower régime era — the bankers

failed to provide the necessary money, and the project, which had the modern department store idea as a foundation, failed.

Mention should also be made of the tower in San Francisco, the only one on the Pacific Coast, owned by the Selby Smelting and Lead Company, succeeded by the American Smelting and Refining Company of New York, which was destroyed by the fire of 1906 and later rebuilt at Vallejo Junction, where it is still being operated. The dominant spirit on the Pacific Coast was A. J. Ralston, for years identified with the smelting, refining, and manufacturing business, whose benign personality is, though he died ten years ago, still a controlling influence in the conduct of the Blue Lead business of the entire country.

Of the twenty-five Shot Towers active in the business in 1890 there remain standing today but two, the one at Baltimore and the one in Philadelphia, and these stand as memorials, mute testimony of a business that three or four decades ago was the pride of many cities, the fear-instilling objects of children who associated shot towers with ghosts and looked upon them as dungeons; the abiding place of gnomes and goblins. All were sold by the American Shot and Lead Company to its successor, the United Lead Company, for fractions of what they cost to erect, and the business, which formerly in order to be profitably managed was intermittently controlled by pools which boasted Boards consisting of a dozen or more presidents with their monthly meetings, generally at Niagara Falls, gave up its ghost and is today a side issue and incidental to the manufacture of ammunition. All ammunition companies now have their shot-tower adjunct and they embrace the Winchester Repeating Arms Company of New Haven, the Remington U. M. C. Company of Bridgeport, the Peters Cartridge Company of Cincinnati, and the Western Cartridge Company of Alton, Illinois. The Selby tower of Vallejo Junction, California, the Lawrence tower at Omaha, and the United Lead Company tower at Perth Amboy still remain, but their business has dwindled to almost nothing. A demand for Air Rifle Shot and so-called Buck Shot still remains and some export business is done, but the business could not continue except as incidental to the varied lines of other lead products manufactured by the owners. No fortunes, even as they were understood thirty years ago, were ever accumulated in the shot business, perhaps for the very reason that it was in large measure looked upon as a side line to

other Blue Lead products. The story might be different if it had been handled as a business by itself, in which case the country would certainly never have boasted of twenty-five shot towers. In its heydey the volume in dollars and cents amounted, at the prevailing price of lead, to about $2,500,000.00, — not large enough in these days to operate successfully one shot tower, yet in those days this business had to stand the burden of supporting at least a dozen executives and their offices and selling staffs, — which if

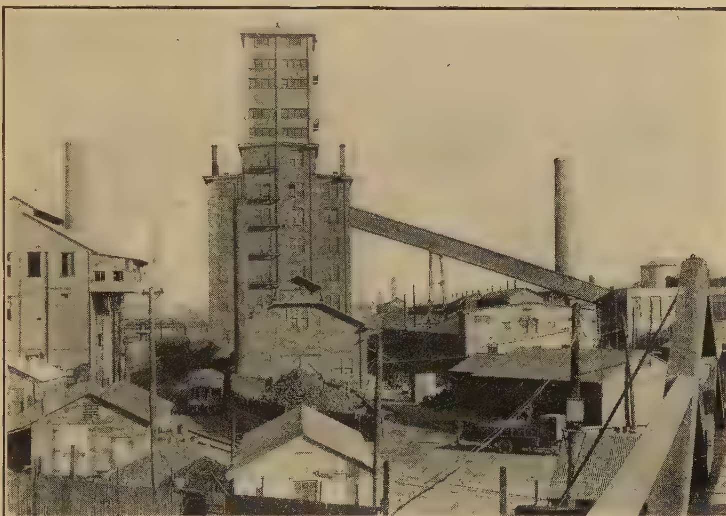


FIG. 6. — A modern Shot Tower.

analyzed is a sad commentary on the generally accepted theory that competition is the life of trade. It would border upon the ludicrous to estimate the amount of money that was economically lost in this business, but if one were to do so by constructing a balance sheet at the height of the business and compare it with one at the time the business was completely surrendered to the ammunition business, with an allowance of only bank interest for the money invested, the loss would approximate several million dollars. And yet in periods the business flourished, due to the pools formed from time to time. A frightful price was paid by the hunter and sportsman, however, for the luxury of supporting twenty-five shot towers which under proper and wise governmental control might have been avoided, but of course at the expense of the com-

plete demolition of the theory, so well exploited by politicians, that competition is a necessity.

In the manufacture of shot the principle has been little changed in the last hundred years. Towers or high dropping floors are still required, though by the employment of a blast of air to counteract the fall of the shot the great height of former towers is cut down by at least fifty feet. There has been great refinement and improvement in handling the shot once it has reached the water in the well at the bottom of the tower. These various steps in finishing include drying, sizing, and the discarding of the imperfect shot by means of glass tables slightly inclined, over which the shot is made to roll. The perfect pellets gain a momentum in this step that makes them readily jump over the gaps and chasms provided, which the imperfect ones find impossible to negotiate and thus they are automatically cast aside to be remelted.

White Metals. By this term is understood the business of alloying and treating metals consisting wholly or in part of Lead, Tin, and Antimony, resulting in products in almost universal demand attendant upon industry. They comprise grid metal, consisting of lead and antimony used in storage batteries; solders of all grades made principally of lead and tin; Babbitt Metal, composed almost entirely of tin, lead, and antimony with an admixture of copper, nickel, and other metals in some grades; casting metal, which is largely antimony and lead; pewter, consisting of lead, tin, antimony, and copper; type metals made of lead, tin, and antimony; and numerous other alloys made up on formula for special uses. The industry is generally known as the Mixed Metal business and is carried on throughout the world where wheels revolve and the raw material is available. Of necessity, if the demand is not large and where the raw material is to be had as virgin or secondary metals, most of the products mentioned may be produced in a small way with the use of a kettle. Thus in numerous instances a Babbitt Metal, a type metal, or solder may be produced in the smallest village with the simple equipment of a kettle, and the production of one day might be large enough to satisfy the demand of such a locality for an entire year, depending altogether on the number and character of the wheels revolving at that place or the number of seams to be soldered.

It will be readily understood that this line of industry must have had a very small beginning almost anywhere as the industrial

demand made itself felt, and in these days of high and specialized effort manufacturing operations are conducted in numberless places, though the specializing tendency of the times has concentrated at a few important points large plants which devote themselves exclusively to the mixing of metals for use in all channels of trade and industry. The intensive research work of these larger plants, the capital at their disposal, the engineering talent employed in manufacturing and selling to study all problems of bearings under all strains and stresses, the service thus rendered — all these factors combined have gradually developed a situation, still in its infancy, that must have the effect of centralizing these activities in still larger plants and the complete extermination of the small and unscientific concern still engaged in this line.

One may easily vision the beginning of this industry, whether here or in Germany or elsewhere, and yet in the misty view there unfolds one Isaac Babbitt of Boston, the inventor of the original alloy which bears his name. The original formula was composed of 88 parts of tin, 4 of copper, and 8 of antimony. He announced his discovery in 1839, and so important was the event that the United States Congress voted him $20,000.00. The original formula has in the course of time been greatly improved and it is generally recognized now that each bearing has its own particular problem which is left to bearing engineers to work out, and which may call for a totally different formula to insure the best anti-friction quality.

What has thus far been said may be best illustrated by a brief history of what is now the largest company in the world specializing exclusively in the manufacture of mixed metals of the White Metal variety. In 1873 Charles C. Hoyt in company with Amos C. Mann, a supposed expert in the manufacture of Babbitt Metal, and E. R. Hoyt, who constituted the office force and factory, began the manufacture of Babbitt Metal and Solder in a rear room of a plumbing shop at 218 Locust Street, St. Louis. A year later Charles C. Hoyt and Charles E. Spooner formed a partnership to conduct this business. A year later the firm became Hoyt and Clark, and in 1878 the two Hoyt brothers formed the Hoyt Metal Company. Today it is the principal subsidiary of the United Lead Company, becoming a constituent in 1903. It has branch plants at Perth Amboy, N. J., Toronto, Canada, and in London, England. It confines itself to the manufacture of all kinds of mixed white

metals and the rolling and extruding of these metals in pipes and sheets. Its business is antimonial lead; battery or grid metal is especially important, an incident worthy of mention because when antimonial lead was first produced as a by-product of a lead smelter following the discovery of silver-bearing lead ores in Leadville, Colorado, in the seventies, the Omaha and Grant Smelting Company, now a part of the American Smelting and Refining Company, found it difficult to market this new by-product. The yearly production at first barely amounted to two hundred tons, yet those Western concerns who undertook to market it found themselves almost financially swamped in their effort. The Hoyt Metal Company later undertook the task, successfully, and soon became known throughout the country as the sole source of supply for this seemingly worthless metal. To E. R. Hoyt, who is still alive and active, though retired, must be given the sole credit for encouraging the use of this by-product in many different lines. The alloy, once a drug on the market, has become the most important in point of volume in the white metal lines. An estimate of the annual tonnage — which would embrace antimonial lead, the by-product of a smelter; the alloy composed of virgin lead and antimony; and that recovered from salvaged battery plates and drosses and residues — would easily run over 100,000 tons per annum. During the World War several hundred thousand tons of the alloy, consisting of 87½ parts of lead and of 12½ parts of antimony, were used in the manufacture of shrapnel balls. A large percentage of these balls were salvaged at the close of the war, with resulting demoralization of market values of the alloy and unstable business conditions for a number of years following the signing of the Armistice.

The National Lead Company, at its branches in St. Louis, Chicago, Cincinnati, Baltimore, and New York, is extensively engaged in the mixing of metals, principally solder and Babbitt Metal. The Magnolia Metal Company has had for many years a wide distribution of a branded Babbitt Metal, but the business of selling branded metals is becoming increasingly difficult with the growth of large consumers who have acquired the practice through their own research and technical departments to specify their own formulæ.

A large percentage of white metals sold for consumption are not consumed in the sense that the metal after use becomes useless.

It is recovered and salvaged after it has performed its function, and in this form it is classified as secondary metals. These require a furnace operation to restore them to further use. When a Babbitt bearing is worn out, the loss of metal by wear is almost negligible, yet a new bearing must be poured to replace it. The one removed is junked, and finally, through the channels of the junk man, finds its way, mixed with other junk metals of this class including drosses, to the furnaces operated by the various concerns in this line. If the metal is clean, a refining process in a pot may be all that is necessary. If it is contaminated with impurities and other metals, it is treated in a reverberatory furnace or a blast furnace. There are numerous concerns engaged in the business of mixing and smelting metals of this class, and there is scarcely a city or town that may not boast of some establishment where the mixing process is not carried on. With increasing importance of the city industrially, these establishments are also equipped with reverberatory furnaces, but the blast furnace is only to be found in the larger establishments, few in number. There are probably not more than a dozen of these in operation at this time.

The Federated Metals Company is one of the important concerns operating in Chicago, New York, Pittsburgh, Detroit, St. Louis, and San Francisco. This company is a recent consolidation of the Great Western Smelting and Refining Company of Chicago with plants in other cities, the Duquesne Reduction Company of Pittsburgh, and the Union Smelting Company of New York and Newark. Another company of long standing is the Nassau Smelting and Refining Company of New York. Establishments of lesser importance are located in most cities. The controlling ones have as a larger and more important element in their activities the smelting of secondary Red metals, comprising copper and brass, the tonnage of which outweighs by far the volume of White metals. It is a moot question as to whether secondary metals thus recovered by smelting and refining are the equal in quality to alloyed virgin metals. It is a fact, however, that new metals alloyed command a higher price than those known to have been recovered from secondary metals and drosses.

A very revolutionary process was discovered and patented in 1923 by Henry Harris of London and, curiously enough, almost simultaneously by Dr. G. W. Thompson of New York, Chief Chemist of the National Lead Company; both processes, though

similar in object yet much unlike in practice, having for their end the separation of non-ferrous metals by chemical action instead of by heat as in a furnace. An alloy consisting of lead, tin, and antimony by these processes may be treated so that the tin is removed, leaving lead and antimony which is marketable as antimonial lead, or the process may be carried along another step by the extraction of antimony, leaving commercially pure lead as a result. The extractions of tin and antimony are put into marketable condition by smelting or electrolytic action. The processes, known respectively as the Harris and Thompson processes, promise to revolutionize the smelting industry of these secondary metals. In the last two or three decades there were times when the smelting of secondary metals, drosses, and residues resulted in accumulations of lead, tin, and antimony alloys to the point where the market was glutted with them. They could not be sold as new metals and an effort to turn them into cash usually resulted in their sale at prices ranging from one to three cents under the price of new metal values of their content. These abnormally low prices were probably the cause of throwing distrust on their quality. At any rate, the fact remains that virgin metal alloys found more ready sale at their actual values plus cost of alloying and proper profits than these refined secondary metals.

The Harris and Thompson processes, owned by the National Lead Company, will in all likelihood overcome what prejudice there has existed in so-called recovered metals. The process, chemical in nature, may more properly be called a cleaning process, and since no heat is used it is contended that the metallic quality of metals treated is improved rather than deteriorated. Physical and chemical tests appear to confirm this contention. Two plants are operating on this process at this time: the Matawan plant in New Jersey, owned by the National Lead Company, and the Hoyt Metal Company plant at St. Louis.

An alloy consisting of lead and one to three per cent of tin has been used for the last forty years in producing Cable Lead, which is the covering employed in protecting strands of copper wire for the telephone and telegraph. In recent years antimony has been used instead of tin. These cables are placed underground in the cities and carried on poles in the country. The wire strands thus encased are extruded in hydraulic presses in one operation and the product is a familiar sight wherever telephone or telegraph wires

are strung in numbers. With the sole exception of White Lead, the industry of encasing cables with lead probably consumes more lead than any other product and, because of its rapid growth, it gives promise to be the principal consumer in the very near future.

Type Metals form an important part in the Mixed Metal business. Lead, tin, and antimony are the raw metals used in their manufacture, and various formulæ are used for Linotype, Monotype, and other typesetting machines. The metal is produced with the utmost care, and the use of secondary metals in their composition is avoided by manufacturers who specialize in this product. The firm of E. W. Blatchford and Company, heretofore mentioned, of Chicago and New York, dominate in this line.

Casting metals, composed principally of lead and antimony, are used in large volume for articles finding a market in the hardware trade, coffin trimmings calling for a large tonnage. In these, the casting quality of the metal is of extreme importance. Antimonial sheet lead and pipe are used increasingly in the chemical trades in contact with certain acids and under certain temperature conditions. A recent invention of G. H. Worrall of St. Louis, marketed under the name of Crawlproof Lead, is manufactured out of what is commercially known as Chemical Lead, with a backing of antimonial lead staves, giving the sheet great strength and stiffness.

Frary Metal, discovered and patented in 1915 by Dr. F. C. Frary and Dr. Sterling M. Temple, members at that time of the faculty of the University of Minnesota, is an alloy produced electrolytically by the Keokuk, Iowa, plant of the United Lead Company. Its need was suggested at a time in the early stages of the World War when the tremendous demand for shrapnel balls on the part of the warring nations ran the price of lead and antimony to unheard-of figures — antimony at one time selling at forty cents per pound, when its normal average over a pre-war period of twenty years was around seven cents per pound. While the price seemed prohibitive, there was far greater concern over the scarcity of the metal, which at times approached famine conditions. The need of a metal possessing ballistic qualities to supplant antimonial lead was most urgent, and this led to Frary Metal, whose composition is 98 to 99 per cent lead, the remainder barium plus calcium. It possesses all the characteristics of lead together with hardness to a degree, measured by Brinnell test, in excess of lead

containing $12\frac{1}{2}$ per cent antimony, in addition to which it is resonant, not falling much short of bell metal — an anomaly when considered in terms of the characteristics of lead, a metal generally regarded as soundless.

The newness of the metal, however, cast grave doubt on its stability, even though tests by various arsenals in the thick of the War showed it to possess even superior ballistic qualities than the regulation lead and antimony shrapnel ball. The greater specific gravity of the new metal, approximately that of lead, was given as the cause of its superiority, but not sufficient time could be allowed to test its stability for use as a war material. Frary Metal was found to possess, however, ideal qualities as a bearing metal where tin was an important component, and as tin reached the value of $1.00 per pound during the War, a very considerable volume of Frary Metal was used in displacing high-grade Babbitt. It is still called for as a bearing metal and its manufacture at Keokuk by electrolytic process is regarded as a permanent industry, a legacy of the War.

There is not much to be said of the improvements developed in mixing metals. Kettles are still used as of old to melt the metals. They have become larger in the more important establishments — some with a capacity of 100 tons — and the method of pouring the finished metal into pigs and ingots has undergone labor-saving refinements. The principal saving is in the handling of the metal once in molded form by means of electric trucks. The modern laboratory is responsible for improvements in alloying and perfection of the finished metal. The electric pump is now largely used in discharging the molten metal from the kettles. And here, too, the great improvement lies in modern, well-lighted buildings, which are now deemed almost a necessity for effective work and for the well-being of the operatives. It is generally recognized by the important concerns that the health of the men is of prime consideration, and a modern factory is equipped with the latest devices to insure the health and safety of the men employed.

Trade Methods. Volumes might be written of the development of trade practices during the last century. It is perhaps natural to conclude that with the advent of railroads, telegraph, telephone, and more lately the automobile, these factors alone contributed most toward increased efficiency of trade and distribution, but in these the business under review does not differ in any wise with

the great improvement recorded in all lines of industry. To the amazing advance in these factors must be attributed primarily the growth of all industry, for they are responsible for the distribution of population, the duplication of towns and cities, and the creation of a multiplied demand for products which otherwise could not develop or exist. And, curiously enough, the later advent of the telephone and radio resulted in cementing these countless villages and towns into one vast community boundless in extent.

By these tokens the growth of these lines of industry is not surprising and there need be no effort made to explain it. To no one man, nor set of men, may be given the credit of the increased consumption, measured in thousands of per cents, of lead pipe, sheet lead, shot, or mixed metals. Their growth was incidental to the discoveries and inventions in other lines which drew these products in their wake.

The interesting feature in the study of the history of trade methods and practices of these lines lies in the growth of ethical conduct both in manufacturing and selling. One need not go back many decades to find manufacturers so distrustful of one another that friendly and sensible intercourse between them was next to impossible. Distrust, born of jealousies and perhaps of deceit, was most common, and fierce rivalry in trade was more often the rule than otherwise. The fine coöperative spirit, which unfortunately is none too much in evidence today, was lacking almost completely. The Golden Rule was unknown; the spirit of Live and Let Live seemed not to have been born, and in its place we find in some of the records of old-time pools the most rancorous feeling developing between the members of these doubtfully benign organizations. Many meetings were broken up by the passing of a lie and, under such atmosphere and bitter feeling, small is the wonder that the succeeding months were spent in bitter warfare, price cutting below cost, skimping of weights, misbranding products, deliberate deceit in composition of materials, misbilling, overshipping, and the employment of a dozen other devices to get the best of the competitor.

The first really serious struggle between the LeRoy and Tatham groups of manufacturers in New York was one involving a patent on the hydraulic press. This noteworthy case caused a bitter legal battle in the courts for years, during which time it may well be

imagined there was no profit in the manufacture of pipe either for the principals involved or for their competitors. When these legal difficulties were adjudicated it is more than likely that pooling of interests was inaugurated, under which for a year or two, doubtless by extortionate profits exacted, some of the cost of the legal battle was recovered, but at the expense of increased competition — at least these old-time pools were noted as breeders of competition, and each recurring pool had for its effect another competitor or two in the immediate vicinity which in due course was subdued or bought out by the formation of another association of this nature. Pools were perfectly lawful, and in these days it borders on the ludicrous to contemplate the blandness of these earlier manufacturers when we find them notifying their trade by open circular that a pool had been formed and that prices from that day on would be firmly maintained without favor to anyone, this laconic notice followed within a few months by another one to the effect that owing to the outrageous action on the part of a competitor in violating his promise, pipe, sheet lead or shot, in whichever article the pool operated, might again be bought below cost. "We will not be undersold," the missive would read. Strange, too, were some of the trade practices. For instance, in Shot in the Eastern district it was customary on an advance in the price in the Spring to bill customers with their full requirements without consulting the customer, the bill being dated, say, September 1st. If the price was maintained during the season, or perhaps advanced, the Shot would be taken out in the Fall. If the price declined, the customer was under no such obligation and the customer usually received these *pro forma* invoices from every manufacturer in the Eastern district so he might choose his supply in the Fall as his desire willed. Small wonder no great fortunes were accumulated, and yet to this day there are some concerns who resort to practices somewhat similar. Small wonder, too, that they find making headway difficult. Fortunately, for those who stand firm on business principles, these others are small in number and what might be termed beginners, whose education in the art or skill of making a reasonable return on the investment is still in the making.

Pools were in charge of custodians or secretaries, and these functionaries commonly took care of four or five pools in different lines. Lead Pipe, Sheet Lead, and Shot were handled in the East by James E. Grannis and later by E. W. Lowe. In the West

these associations were looked after by F. B. Lawrence, who later became president of the Lawrence Shot and Lead Company in Omaha and who died in New London, Conn., in 1920. Both Grannis and Lawrence were ably assisted by W. T. Morgan, who later, in 1883, associated himself with the Raymond Lead Company in Chicago and was manager of that concern when he died in 1924.

The Sherman Anti-Trust Act put an end to pools. The passage of the act in 1891 cast gloom upon the business world, and doleful predictions of disaster to manufacturing were to be heard on street corners. Just prior to its enactment, pools in the larger lines of industry had given way to the trust form of organization of industry, which in brief was the placing of the various plants under the control of a Board of Trustees, and against the value of these plants were issued Trust Certificates. The Sherman Act was particularly directed against these trusts, but pools were also included in its inhibition as well as all agreements on prices. The National Lead Company, engaged in some lines covered in this review, was one of the earliest trusts and was one of the first to change its trust form to one of corporate existence, under which it is still operating. The American Shot and Lead Company, the so-called Shot Tower Trust, was planned as a trust, but as the sentiment of the country was rapidly crystalizing against the trust form of organization it was deemed best to organize as a corporation under Illinois law and its charter was obtained in 1890.

Probably no national legislation, with perhaps the sole exception of the Volstead Act, received such widespread condemnation from organized business as the Sherman Act, and to this day associations are active to modify the law. Following its passage there were many pools covering the smaller lines of industry, but these were operated under cover of strictest secrecy. There were many secret price agreements, and it is not at all unlikely that the law is being violated at this late day in small communities, but numerous prosecutions and convictions under its provision gradually lessened the efforts to defy the law, and in the larger and nation-wide lines of industry it is undoubtedly respected in letter and spirit.

Whatever may be said in condemnation of some of its drastic provisions, the thoughtful industrialist will be compelled to confess that the almost complete acknowledgment of the law has elevated enormously the ethics of business; that a new era was created thereby under which, to express it homely but forcibly, real men

have come into being in industry — men of character and force who have come to realize that to make a reasonably profitable return on investment they must attend to their own affairs irrespective of what their senseless competitor might be doing. The slogan, "We will not be undersold," finds no place in modern business, if by "undersold" is meant a price that means no profit. The successful money-making concerns of today are they who mind their own business, know their costs, and will not sell their product under a price that spells a fair and reasonable profit. And, as is logically to be expected, such a course must bring into active being the Golden Rule and a friendly and coöperative spirit without the necessity of secret meetings to fix prices — in short, the spirit of Live and Let Live. The wise manufacturer has come to realize that to try to do all the business or more than his reasonable share spells ruin to profits. Under this new order of things where its practice is in evidence, deceit and deception of pooling days have disappeared almost completely and manufacturers in the same lines have become friends whose confidence in one another is not easily to be shaken. In the opinion of the writer the Sherman Law, more than any one agency, is responsible for this.

Labor Conditions. Except for machine work on dies and repairs, labor employed in this industry is common and semi-skilled. Machinists are employed only in the more important plants where larger equipment make repairs a continuous necessity. The smaller plants depend on outside shops for assistance in the emergency of repairs. The semi-skilled workmen are those in charge of hydraulic presses, whose training at the one post of controlling pressures in the operation of the machines and in superintending the relatively small force required in the production of one unit makes them skilled to the point where they may not readily be replaced. This is equally true of the one who operates the rolling mill where extreme care is required to roll to exact dimensions. In shot dropping, the one having charge of the dropping of the shot and arranging the proper mixture of the drop may also be classed as semi-skilled, but their number in the aggregate in all branches of the industry is small — certainly not large enough to be classified as a trade. The workers are of course more numerous but above the average intelligence of common labor, yet they may be classified as such. Wages are somewhat better than what are ordinarily paid to common labor, and strikes

and general dissatisfaction are unknown. In the plants of the larger companies especial attention is paid to the well-being of the men and sanitary conditions are carefully looked after. Dressing rooms and showers are provided and the men are importuned to observe the sanitary regulations. Lead poisoning is practically unknown and the risk of it is negligible except where men are employed at furnaces in the reduction of drosses and residues. Here especial care is observed and the men are required to wear respirators to prevent the inhalation of poisonous fumes or dust. As an indication of the longevity of some of the men in the industry, there was recently pensioned at one of the plants in Baltimore a man who had reached the age of 78 years and who had been continuously employed in the factory for fifty years. He had steadfastly refused earlier offers of pension. Similar cases are not uncommon.

Wages differ with the locality. The rate is easily 100 per cent greater than in 1913, and this also represents approximately the higher rate paid in this country over wages in similar industries in England and Continental Europe.

Export Trade. The trade with foreign countries in this industry is rather limited and confined principally to Latin American countries. It is done largely on a draw-back basis under which duties paid on imported raw materials are recovered from the government on proper evidence of import, manufacture, and export. Even with this advantage, the industry is handicapped in its foreign trade by competition with England, Germany, and France, because of the much lower wage rate ruling in those countries. Yet a certain volume of foreign trade has always been done, due to the superior quality of the product where price is a secondary factor. Specialties, as for instance products of antimonial lead, are exported at times in large volume, even to European countries, but this is because the exploitation and manufacture of antimonial lead was primarily of American origin and the demand in any one foreign country is barely large enough to warrant the installation of equipment to cater to local needs, not to mention the lack in such countries of specialized skill required in the manufacture of this class of products.

The import duty on products in these lines is very meager and does not begin to cover the increased cost of manufacturing in this country. The tariff on Pig Lead, the raw material, is $2\frac{1}{8}$ cents per pound, and on manufactured products $2\frac{1}{2}$ cents per pound, which

means a protection of but $\frac{3}{8}$ cents per pound on the manufactured article, far from sufficient to take care of labor costing more than double the European rate. Yet the importation of products is negligible primarily because the business may be said to be largely local. Lead Pipe, for instance, does not lend itself well to transportation and is easily damaged. Sheet Lead is rolled largely on specification and cannot be called staple, and it is doubtful whether the critical American demand as to quality in all of these products could ever be satisfied by factories thousands of miles distant. Moreover, market risks are a deterrent to import in large volume.

To sum up, this country is by far the largest market for these lines, as indeed it is for most other lines, and with its ever growing wealth and rapid development must continue so indefinitely. The principal problems are purely local and, though they are perplexing at times, the solving of them may be safely left to the good sense of the leaders in the industry.

CHAPTER XII

THE LEATHER INDUSTRY

By Allen Rogers[1]

Importance of the Industry. Leather and its manufactured products, according to the 1925 Census of Manufactures, total annually in value one and three quarters billions of dollars, of which shoes amount to almost a billion. Over 4000 establishments employ 315,000 wage earners.

Second only to the shoe-manufacturing trade is the tanning industry, which is the specific subject of this article. There are in the United States today 532 tanneries, giving employment to 53,000 persons, and according to the statistics for 1925 are producing a product valued at $462,000,000. Our tanneries require the skins from 127 million animals, which include cattle, calves, goat, and sheep, or more than one animal's covering for every man, woman, and child in the United States.

Tanning. The production of leather from the pelts of animals is probably the most ancient of all the arts. Leather manufacture was no doubt practiced by prehistoric man, as is proven by many relics which show that agriculture is a much later stage of development than hunting. It is well established that the human race first subsisted on the flesh of animals, and as man was not protected against the elements he naturally sought comfort and warmth as a source of clothing from the pelts of those animals taken in the chase.

As wet skins soon putrify and decay, and as dry ones are hard and horny, we cannot but assume that the hunter soon found a remedy for this by working into the pelt the fat and brains of the animal itself. The principle of this process has been handed down from antiquity and is essentially the same as used at the present time for the dressing of furs and for the production of so-called chamois leather.

[1] Pratt Institute, Brooklyn, New York.

That certain vegetable tanning materials such as hemlock bark, oak, chestnut, and other tannin-bearing substances were familiar in our earliest civilization is shown by specimens discovered in ancient ruins, and which are available in many museums. The smoking of leather was practiced many centuries before the Christian era, and the use of alum as a preservative has been known for thousands of years.

During the past half century more progress has been made in the art of tanning and the science involved given more attention than in all previous time. This is due, of course, to the fact that all matters scientific have received much attention during this period, and leather manufacture has come in for its share of scientific investigation, research, and development during this great scientific era. The one great discovery which revolutionized the leather industry was the introduction of chromium salts as a means of leather production. This discovery is of American origin, of which we are justly proud, for its use furnishes a leather with greater wearing quality than the vegetable-tanned product and is cheaper to produce. In fact over ninety per cent of our shoe-upper leather is of chrome tannage; while many other varieties of leather formerly of vegetable, alum, or oil tannage are now produced by the chrome process. We are now approaching a new era in which synthetic materials are finding application and becoming more and more important.

In our own country leather manufacture was first established in the New England States, due of course to the unlimited supply of hemlock bark then available. Small tanneries were scattered over this section, but more especially have the towns of Salem and Lynn been looked upon as the birthplace of the leather industry in this country. As the supply of bark became depleted in New England the industry moved to other sections and for many years Pennsylvania was the largest center for heavy leather. As the population grew tanneries sprang up all over the country.

Although these tanneries are very widely distributed there is still a tendency to segregate, and we have certain localities that may be termed leather centers. These centers are Salem, Lynn, Peabody, and surrounding towns, where calf- and sheep-skin tanneries predominate, although a great deal of side upper and patent leather is made in this locality. The second center is Philadelphia and Wilmington, which may be considered the home of glazed kid and

the goatskin industry. Middle and western Pennsylvania ranks high as a sole-leather center. Newark, N. J., has many tanneries, the largest number of which are engaged in the production of automobile and upholstery leather. Chicago and the territory to the north as far as Milwaukee have large leather interests and furnish considerable quantities of sole, calf, side, patent, and furniture leather. Several large tanneries are located on the Pacific Coast and throughout the South. St. Louis, Mo., has held the reputation of being the fur center of the world. Northern New York and Ohio come in for their share of the business. Gloversville and Johnstown rank foremost in the production of glove leather.

Perhaps there is no large industry about which the general public knows less than the manufacture of leather, and so it may be of interest to outline in a brief manner the salient points which make for the production of this most necessary and important commodity. In the first place, when talking of leather, we refer to the raw material as either hides or skins. By this we mean that the pelts from large animals such as the steer are termed hides, while those from the smaller animals such as calf and goat are known as skins. There is a stage of growth, however, between the calf and the cow when the covering is neither a hide nor skin, but is known as a kip. Hides and skins of the most importance from the standpoint of leather production come from such animals as are killed for food. We do have also certain hides and skins in which this is not the case, but these are of minor importance.

As it is not within the scope of this article to enter too deeply into detail, we will simply consider a few of the most common types and briefly notice the general method of procedure employed in converting the pelt of an animal into finished leather. Steer hides are taken from such animals as are killed for their beef. According to the method of slaughter we have " cut throats " and " stuck throats." The first are from those animals killed under the Rabinical Law for consumption by the Jews and the second from animals killed for the Gentile trade. Hides come to the tanner in various conditions, such as " market," those taken from the animal and used by the tanner without previous cure; " green salted " are the hides that have been preserved by piling down in salt; " dry salted " are hides which have been salted and then allowed to dry; while " flint hides " are those which have been dried

without previous salting. Hides coming into the country from foreign sources are usually named from the port of shipment.

Hides are classified according to their weight, being known as heavy, medium, light, extreme, and spready. They may be graded for scores, cuts, and grubs, and according to "take-off" are known as "packer," "city," and "country" hides.

Manufacture of Sole Leather. When the hides arrive at the tannery, they are assorted into the various grades and placed in piles as illustrated in Figure 1,[1] which shows a modern hide cellar. It will be observed that the hides are in bundles. This is done

Fig. 1. —Hide Cellar.

for ease in handling and for the purpose of keeping them moist. When ready for use they are made up into packs, the number of hides in a pack depending upon the capacity of the plant. After trimming off the undesirable portions the hides are soaked in water to remove dirt, salt, blood, and manure and at the same time to bring them back to a soft and pliable condition as when they came from the animal's back. The next operation is that of loosening the hair and epidermis, which is accomplished by soaking for several days in a solution composed of milk of lime and sodium sulfide. The pits used for this purpose may be seen

[1] The illustrations in the sole leather description were taken from Practical Tanning by the author of this article and were furnished to him through the courtesy of the Ladew-Jones Co., Newark, N. J.

in Figure 2. The hair and epidermis having been loosened, the hide is worked over a machine to scrape off this loose material

Fig. 2. — Lime Pits.

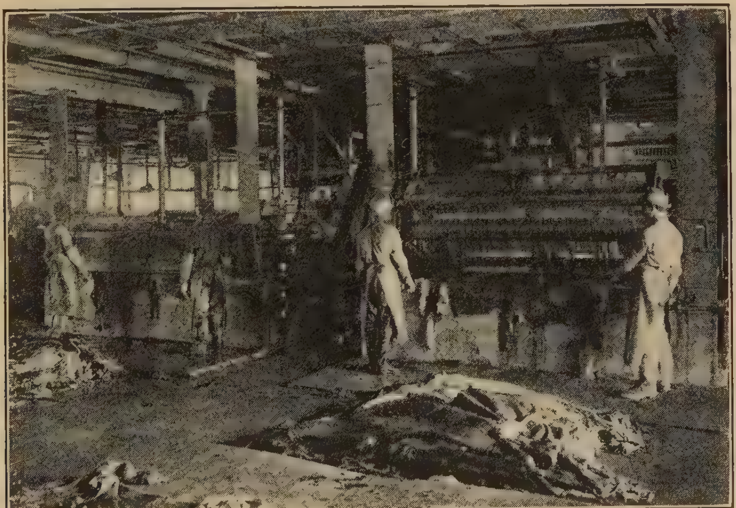


Fig. 3. — Unhairing Machines.

and clean the grain. Such a machine is shown in Figure 3. A somewhat similar machine is used for the removal of excess flesh on the under side of the pelt. The clean stock is again returned

to clear water, where it remains suspended over night to remove the surface lime and allow for a slight plumping. To hasten the plumping and removal of the lime it is often good practice to add a small amount of some acid, such as lactic acid.

The tanning operation is accomplished by suspending the hides in pits containing a solution of tanning materials such as hemlock, chestnut, or quebracho extracts, and may consume from thirty to ninety days, depending upon the process employed. Figure 4

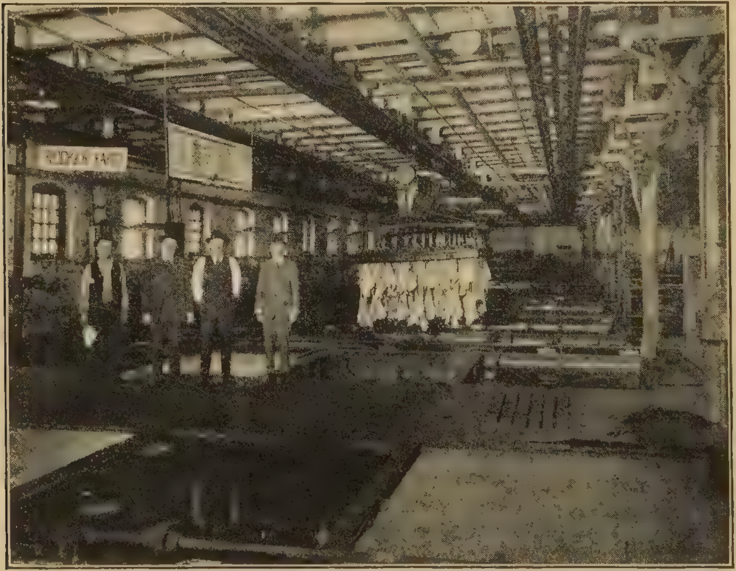


FIG. 4.—Tan Yard Showing Rockers.

shows the hides as they are ready for the first liquors, called the rockers, while Figure 5 shows the hides as they are removed from the final liquors, called the layers. As the hides come from the final layers they are completely tanned, but to give better cutting values they are placed in drums and filled with heavy liquors. This process is known as extracting and is well illustrated in Figure 6.

Following extracting the stock is placed in tempering pits to allow the tan to set and then the hides are bleached, filled, and dried. When dry the stock is slightly dampened and worked under heavy rollers to obtain a compact and firm product.

It will be noticed from the above brief description of sole leather manufacture that of necessity there must be considerable labor

Fig. 5. — Tan Yard Showing Layers.

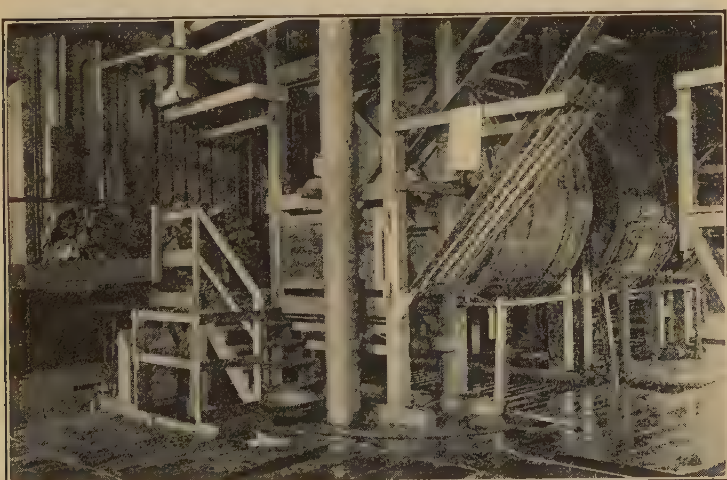


Fig. 6. — Extract Wheel.

involved. As the average time from entering the stock to the production of a finished leather runs from ninety to one hundred and twenty days the capital invested in hides alone amounts to a

considerable sum of money. Thus a plant having a capacity of 500 hides per day at the rate of ten dollars per hide has an investment of $5000 per day for each of the 120 days or $600,000 tied up in hides while they are going through the tanning process. If we add to this the value of the finished leather held for sale or shipment, the hides held in storage for daily operation, the value of the tanning materials, and the item of labor and power required, it will be plainly seen that the operation of an average-sized sole-leather tannery is no small financial undertaking.

FIG. 7.—Bate Paddles.

Manufacture of Upper Leathers. In the production of shoe-upper leather cattle hides are likewise used to quite an extent; but in this branch of the industry they are handled in what is known as sides. For shoe-upper leather other sources of raw materials are also employed; the most important being calfskins, goatskins, kangaroo, and colt. The same preliminary treatment is necessary with this grade of stock as described under sole leather; but following the unhairing the stock is subjected to a treatment known as bating. This operation consists in treating the limed skins with a solution containing a deliming agent and pancreatic enzymes. This procedure removes the lime and cementing material between the fibers and brings the stock to a soft and flaccid condition. When thoroughly bated the skins are pickled with salt and sulfuric acid to prepare them for the tannage. Over ninety per

cent of all shoe-upper leather is of chrome or mineral tannage, which is accomplished by treating the pickled skins with a solution containing salts of the metal chromium.

In the production of upper leather there is more need for skilled labor than in heavy leather, and so this item becomes a bit more involved. The capital invested in machinery and equipment is much greater for an upper-leather plant than for a sole-leather tannery, but that invested in raw material is much less per unit of leather manufactured. The number of skins handled per day in an upper-leather plant is many times greater than that in sole leather, thus making the initial investment much greater. The turnover, however, is more rapid, being only at most a few weeks

Fig. 8. — Shaving Machines.

from the time that the stock enters the tannery until it is ready for sale. The production of upper leather lends itself to working on a comparatively small scale, which accounts for the larger number of such plants.

Figures 7 and 8, furnished by The Ohio Leather Company, illustrate a line of bating paddles and give some idea of the labor requirements in one of the necessary operations of shaving.

Other Kinds of Leather. The automobile and upholstery leather manufacturer utilizes what is known as spready hides, that is, hides with a large area. The tanning is accomplished with vegetable tanning materials, but the time factor is of no great importance as the hides are split into layers, often as many as four splits being obtained. These splits allow of rapid tannage, which reduces the financial investment to a minimum.

Belting and harness leathers require a long tannage and are very similar to sole leather processes.

Fancy leather is that commodity used as the name implies. It may be of alum tannage, chrome tannage, or vegetable tannage, to suit the various requirements. From it are made all kinds of fancy articles such as pocketbooks, traveling cases, bill folds, book bindings, and fancy shoes. In this industry much skill is necessary and the labor employed is largely high class.

Without going into detail it might be well to enumerate some of the other classes of leather that are produced, simply to show the wide field into which leather enters and which has given birth to the slogan, "Nothing takes the place of leather." Thus let us notice that we have bag and case leather, strap and harness leather, raw hide leather of various kinds, lace leather, roller leather, whip leather, belt leather, chamois leather, hat-sweat leather, mechanical leather, piano leather, gas-meter leather, coat leather, washer leather, glove leather, sporting leather, and many others. At the same time a list of the animals which go to make up our supply of hides and skins is worthy of note. Thus we have the steer and cow, horse and colt, pig, sheep, goat, calf, lamb, kid, kangaroo, deer, buffalo, alligator, lizard, walrus, seal, shark, snake, ostrich, porpoise, ray, and many others.

Some idea of the size of the industry may be gained from Government reports and statistics compiled by the Tanners Council of America,[1] through whose courtesy much of the following data was obtained. In 1926 the tanning industry of the United States consumed 127,000,000 hides and skins as compared to 119,000,000 in 1925. According to the figures of the U. S. Bureau of Census the following distribution is shown:

	1926	1925
Cattle Hides	22,270,000	22,817,000
Calf and Kip Skins	15,754,000	13,877,000
Goat and Kid Skins	49,776,000	42,486,000
Sheep and Lamb Skins	31,663,000	33,089,000
Other Hides and Skins	7,757,000	7,513,000
	127,213,000	119,782,000

These figures are of interest in showing that business during 1926 was better than during the previous year and indicates that

[1] Compiled by E. A. Brand and J. L. Nelson.

the surplus of stock on hand made necessary an increased production of finished leather.

A study of the following table shows very clearly how certain stocks have been reduced, while others have been increased. It is on account of the reduction of stock that we hear of a depression, for the simple reason that sales are being made from stock on hand

CHANGES — 1926 COMPARED WITH 1925

	TANNERS' STOCKS	PRODUCTION	CONSUMPTION
Sole	43% −	8% −	5% +
Belting	45% −	6% +	12% +
Cattle Side Upper (black and color)	11% −	1% +	3% +
Patent Side Upper	9% +	1% +	
Harness	14% +	9% −	14% −
Bag, Case, and Strap	17% +		6% −
Upholstery (grains)	10% +	4% −	6% −
Calf and Kip — Shoe	11% −	10% +	13% +
Calf and Kip — Fancy	127% +	183% +	148% +
Goat and Kid — Shoe	2% +	17% +	17% +
Goat and Kid			
Fancy and Glove	61% +	41% +	37% +
Sheep and Lamb			
Shoe Stock	10% −	1% −	
Glove	20% −	1% −	1% +
Skivers and Sweats	23% −	32% −	28% −
Fancy and Bookbinding	17% −	19% +	20% +
Shearlings	144% +	27% +	14% +
Roller	17% −	2% −	
Chamois and Other Fleshers	9% +	11% −	14% −
Cabretta			
Shoe	26% −	3% −	2% −
Glove	130% +	23% +	17% +
Fancy	100% +	33% −	40% −
Kangaroo and Wallaby	7% −	17% −	15% −
Deer and Elk			
Shoe	40% −	21% −	20% +
Glove	33% +	5% −	7% −
Horse and Colt			
Upper	7% +	7% +	2% +
Sole	30% −	19% +	56% +
Glove	9% −	5% −	4% −
Seal	15% +	4% +	1% +
Pig and Hog			
Fancy and Glove	31% −	10% +	8% +
Welting	3% −	30% +	28% −

rather than from current production. When stock on hand has increased an increase of production and consumption as a rule is noticed, which of course means activity in that line.

A study of the percentages of stocks on hand, production, and consumption lead us to inquire into the distribution of the various products, and from this to predict what should happen when stocks on hand have been reduced to a normal basis. This is shown for cattle hides in the following table:

Cattle Hide Leather

(000 omitted)

Unit	Tanners' Stocks		Production		Consumption	
	1926	1925	1926	1925	1926	1925
Sole, Side	2,888	5,100	13,615	14,879	15,827	15,069
Belting, Butts	309	559	858	809	1,198	991
Side Upper	1,804	2,038	15,476	15,338	15,710	15,256
Patent Side	742	678	8,678	8,628	8,614	8,608
Harness	297	259	1,169	1,288	1,131	1,322
Bag, Case, Strap	257	219	1,183	1,175	1,145	1,216
Upholstery, Hides	96	87	601	626	592	627
All Others, Sides	194	161	1,501	1,279	1,468	1,357
Total, Sides	6,992	9,747	44,540	45,457	47,295	46,964

It is very interesting to note that sole-leather stocks have been reduced from 5,100,000 to 2,880,000 or by 2,212,000. This accounts for the falling off in production for 1926, but at the same time it is gratifying to observe that the consumption of sole leather in 1926 was nearly a million more sides than in 1925. In the case of belting leather a similar condition prevailed, except that there was an increase in production over 1925. With upholstery leather a little more pessimistic attitude must be taken. Here the stocks on hand have increased, production has fallen off, and consumption is less. This is explained from the fact that the use of closed cars have taken the place of the open automobile, and as a result fabrics have largely replaced leather in their upholstery.

The production of calf and kip leather has been very satisfactory during the past year, as is shown in the following table:

CALF AND KIP LEATHER
(000 omitted)

	Tanners' Stocks		Production		Consumption	
	1926	1925	1926	1925	1926	1925
Upper Skins	3,924	3,982	15,033	13,626	15,091	13,347
Fancy Skins	59	26	705	249	672	271
Glove and Raw Hide . .	1	1	7	2	7	9
Total	3,984	4,009	15,745	13,877	15,770	13,627

The interesting point about the above table is in connection with fancy leather. Dame fashion has called long and loud for some-

GOAT AND KID LEATHER
(000 omitted)

	Tanners' Stocks		Production		Consumption	
	1926	1925	1926	1925	1926	1925
Goat and Kid						
Upper	13,262	12,991	48,919	41,878	48,648	41,515
Fancy and Glove . .	45	28	857	608	840	613
Sheep and Lamb						
Shoe Stock	2,045	2,283	13,973	14,124	14,211	14,281
Glove	447	558	5,297	5,326	5,408	5,362
Skivers	443	574	3,189	4,705	3,320	4,604
Fancy and Bookbinding	267	323	2,369	1,984	2,425	2,016
Shearlings	266	109	2,519	1,985	2,362	2,065
Roller	96	115	827	848	846	854
Unclassified	213	282	3,491	4,117	3,560	4,119
Cabretta						
Shoe Stock	506	688	2,344	2,412	2,526	2,570
Glove	241	105	2,071	1,678	1,935	1,654
Fancy	8	4	62	93	58	97
Chamois and Fleshers .	672	614	3,498	3,919	3,440	3,987
Kangaroo and Wallaby .	342	367	680	820	705	830
Deer and Elk						
Shoe	28	47	430	354	449	356
Glove	20	15	634	665	629	675
Horse and Colt . . .						
Upper	115	107	440	412	432	423
Sole	19	27	112	94	120	77
Glove	37	41	426	449	430	447
Seal	23	20	333	321	330	326
Pig and Hog	9	13	225	205	229	212

thing new and so we see here a large percentage increase in production and a simultaneous increase in consumption. In other words, this has meant an increased business with a busy shop for manufacturers of such leather. The same thing holds good for goat and kid leather, as is shown in the classification for goat, kid, sheep, lamb, cabretta, and other leathers on the previous page.

In a study of this kind it is always a matter of importance to know how production and consumption is influenced by export and import trade. This is seen by observing the following statistics:

Exports and Imports of Leather

Exports			Imports	
1925	1926		1926	1925
Feet	*Feet*		*Feet*	*Feet*
18,624,000	22,827,000	Cattle, Upper	422,000	1,153,000
29,276,000	31,726,000	Calf and Kip	20,212,000	13,392,000
6,487,000	8,190,000	Sheep and Lamb	3,093,000	4,186,000
45,242,000	48,546,000	Goat and Kid	6,734,000	3,134,000
584,000	879,000	Horse and Colt		
36,985,000	30,616,000	Patent (all kinds)	4,945,000	4,856,000
4,045,000	3,003,000	Others	3,705,000	19,275,000
		Lining (calf)	13,668,000	
3,145,000	2,855,000	Wax Splits (lbs.)	253,000	
1,084,000	892,000	Fancy	3,580,000	2,576,000
5,256,000	6,421,000	Glove	272,000	493,000
3,223,000	2,851,000	Upholstery	12,000	5,000
455,000	292,000	Case, Bag, Strap	792,000	392,000
		Pianoforte	8,000	7,000
		Chamois (doz.)	48,000	689,000
Pounds	*Pounds*		*Pounds*	*Pounds*
19,327,000	13,470,000	Sole	7,774,000	6,356,000
		Shoe Parts — Cut	555,000	737,000
184,000	172,000	Harness, Collar, Saddle	997,000	991,000
		Belting	286,000	274,000
		Pigskin	91,000	
		Rough Tanned	10,455,000	9,033,000
12,231,000	10,428,000	All Others	2,740,000	1,597,000
Dollars	*Dollars*		*Dollars*	*Dollars*
52,155,000	49,814,000		28,662,000	22,412,000

A glance will show that the balance of trade is in our favor, but it is a bit disconcerting to note that for 1926 there was a falling off in exports and an increase in imports.

In making comparisons it is often important to know just how much of our raw material is domestic and just how much is imported. This gives us an idea of our dependence upon foreign countries and whether or not we are manufacturing for ourselves alone or have the advantage of a world market. This is seen very clearly by an examination of the following table. This shows that we are importing far more raw material than we are exporting as a finished product. In other words we require for our factories more raw material than can be obtained from domestic sources. This is a very good indication of a healthy business condition.

IMPORTS AND EXPORTS OF HIDES AND SKINS

Imports			Exports	
1925	1926		1926	1925
Pieces	*Pieces*		*Pieces*	*Pieces*
3,817,000	3,361,000	Cattle Hides	1,649,000	1,627,000
4,853,000	7,587,000	Calf and Kip Skins	1,069,000	1,233,000
47,532,000	53,498,000	Goat and Kid Skins	898,000	856,000
		Sheep and Lamb Skins	1,675,000	2,783,000
4,492,000	3,715,000	Wooled Skins	610,000	571,000
20,547,000	19,504,000	Slats		
120,000	549,000	Splits, Fleshers, and Skivers		
617,000	747,000	Kangaroo and Wallaby		
445,000	508,000	Horse and Colt	11,000	19,000
	1,094,000	Deer and Elk		
140,000	137,000	Buffalo	1,000	1,000
7,398,000	6,087,000	All others (lbs.)	12,752,000	8,523,000
Dollars	*Dollars*		*Dollars*	*Dollars*
96,764,000	96,812,000		15,921,000	20,433,000

The data given in the above tables indicate very conclusively that the leather industry in 1926 was in a far better condition than it was in 1925. A careful study must also lead us to predict an increased prosperity along this line for the coming year. This industry like others has its ups and downs, but let us hope that we are now sailing on a rising tide of prosperity.

Labor Conditions. One problem that confronts all branches of industry is that of labor, and the leather industry is no exception. It is not, however, so serious as to cause any great concern. Much of the labor in a tannery is skilled or semi-skilled, and where the

plant is located away from the big centers very little overturn of labor is felt. In the larger centers, however, the overturn is more pronounced, due in most part to the fact that the workmen float from one plant to another.

The tanning industry is not nationally unionized. Working hours and wage rates are usually settled by local tanning associations or by individual companies. The type of workers run from common labor, where strong muscles are more of a requisite than intelligence, to skilled machine operators who require many months of training before becoming proficient. The tanning industry as a whole has often been regarded as "backward" in developing machinery for certain departments, due perhaps to its ability to obtain cheap labor for these departments. While working conditions in some plants are unpleasant, particularly in the "wet" departments, it is not necessarily typical of the industry, for many modern plants are designed to give agreeable working conditions and prevent the bad odors which have made tanneries famous — or infamous.

In the finishing departments, more skilled workers are required. Wage rates are comparable with other manufacturing industries requiring skilled and semi-skilled labor.

Wages in this industry have advanced with the increased cost of living, but unfortunately the selling price of the finished product has not gone up in proportion. In fact, although many plants are showing an increased production, the net earnings are far below a satisfactory or safe margin.

Tariff. Free hides and skins have always been regarded as essential to the life of the American tanning industry on its present basis. For a period of 75 years prior to 1898 (with the exception of a few years during and after the Civil War), cattle hides were on the Free List. Even when the Dingley Bill of 1898 left the House, hides were still on the Free List, but for some unaccountable reason a duty of 15 per cent was added in the Senate as a matter of compromise.

The hide market is world wide in its scope. Between 30 and 40 per cent of cattle hides used by America's tanneries must be imported, and tanners have contended that they should be admitted free of duty. Calf, sheep, and goat skins have never been subjected to a duty, so tariff discussions have centered on cattle hides.

Since hides are a by-product of the meat industry, their production is dependent upon meat consumption, and a duty does not (so tanners have claimed in appearing before Congress) increase the supply of hides nor add to the value so far as the cattle-raiser or farmer is concerned. Little labor is used in producing a hide and it must be removed before the meat can be prepared for consumption. On the other hand, it has been shown that a duty on hides raises the price of shoes, harness, and other leather goods used by the consumer.

Briefs submitted by tanners to Congress point out that there should be no confusion between duties on hides and duties on leather, as they are not comparable. Hides are raw material in every sense, on which little labor has been expended, while leather and shoes require highly specialized labor.

At present shoe leathers and shoes are on the Free List. A few specialized lines, such as glove leather, upholstery leather, chamois skins, and leather for luggage and small leather goods, pay a 20 per cent duty. This rather unusual situation, under a high tariff administration, is the result of the desire of Congress to prevent shoe prices from increasing.

Financial Organization of the Industry. Combinations and consolidations have been consummated in this as in other branches of industry, and like all combinations have resulted in certain good and certain questionable advantages. Combinations have had the tendency to stabilize the market, and through the influence of large organizations helpful tariff laws have been put into effect.

Census figures indicate that in 1879 there were 2347 establishments in the United States engaged in the tanning of leather, while today there are only 532. This reduction is partly due to progress in large-scale production and the elimination of "tub-tanneries" in small communities, but mainly to consolidations and combinations of existing plants which were favorably located for competitive reasons. Corporations which control a number of plants and which have grown up during recent years are concerns like the Central Leather Co., Armour Leather Co., National Leather Co., and American Hide and Leather Co. There are, of course, many others.

The first important consolidation in the industry was the former United States Leather Co., now known as the Central Leather Co. Its history may be regarded as typical and was in fact the first

corporation in the United States to have a capitalization of over 100 million dollars.

The chief reasons for the formation of the United States Leather Co. in the spring of 1893, according to Professor Dewing of Harvard,[1] are contained in the following statement:

> The favorable outcome of the agreement of 1892 (not to wet in hides for six months) and the widely recognized success of the oil, whisky, and sugar combinations led five of the largest tanning interests to consider the possibility of making a more economical use of their bark lands by merging their different interests in one company. The bark for each tannery could then be obtained from the nearest source, — obviously an economy in operation, — and with the control of a large proportion of the available bark, with economical methods of manufacture and decreased selling expenses, the tanners believed they would be able to produce leather more cheaply than their competitors. Then, too, some of the older men were desirous of organizing their business affairs so that their estates could be administered easily in case of their death.

Professor Dewing goes on to state that committees were appointed to appraise tanneries and bark lands owned by the interests that had consented to come into the combination. Approximately 110 tanneries, controlled by some 60 leather houses, were acquired and in addition about 400,000 acres of bark land and the bark rights on nearly 100,000 more. At the outset the Company controlled about 58 per cent of the sole leather tanned in this country. (The present company produces about 30 per cent of the sole leather tanned in this country.)

The hopes of the incorporators were not realized, and unpaid accumulated dividends on preferred stock amounted to 43 per cent by 1905, when the Company was reorganized into the present Central Leather Company. Several causes are ascribed by Professor Dewing to the early failure of the Company. First, the period of general business depression following the panic of 1893 and the relatively long time required for manufacture of leather aggravated the difficulties resulting from the depression; second, the Company was embarrassed by its large holdings of unproductive bark lands which represented a large part of its capital structure; and third, lack of success lay in competitive conditions in the tanning industry. The small, well-equipped

[1] "Corporate Promotions and Reorganizations," by A. S. Dewing, Harvard University Press, Cambridge, 1920.

plants outside of the Company were able to produce more economically and leather prices were fixed by competition, which was not eliminated through the combination as the promoters had hoped.

In 1905 a reorganization was effected and the Central Leather Company was formed. The name of the United States Leather Company was retained as a subsidiary selling company. This reorganization turned on the consent of the preferred stockholders to suffer a reduction in income and the common stockholders a reduction in the par value of their security. As a result both the capital charges and the capitalization were reduced.

Following the post-War depression this Company, like the entire leather industry, suffered losses aggregating many millions of dollars. After a period of producing at half of its capacity, the Company scrapped a substantial number of its plants and announced a reorganization plan to the stockholders, involving a still further reduction in its capital. During the early part of 1927 it was stated that a majority of the stockholders had accepted the new plan and that the corporate title of "The United States Leather Company" would be resumed.

The margin of profit involved in conducting a tannery depends to a very large measure upon personal supervision, the utmost care in selecting raw stock, and attention to minute details in the manufacturing operations. For this reason it is possible for the small tanner to conduct a very lucrative business and compete successfully with the larger organizations. In many of the small plants we often find the owner acting as superintendent of his factory. The merchandizing of leather and the purchase of the raw material plays a most important part in the proper conduct of a tannery. Poor judgment in buying hides or skins may easily result in a financial failure; while excessive cost of manufacture or the production of an inferior article may be equally disastrous. In the fancy leather field there is always present the fear of changing whims. A leather may be selling very strong one week and drop to zero the next. The concern with a large stock of unsalable leather is surely in a bad predicament.

Leather Research Laboratory. A unique development in the tanning industry of this country has been the establishment on the campus of the University of Cincinnati a leather research laboratory. The Tanners' Council of America, the national organization of the tanning industry, built and equipped at a cost

of $115,000 a laboratory building which was given to the University. It is a handsome, three-story brick and concrete structure (Figure 9) containing private research laboratories for the heads of the various departments of the work, general laboratories and private laboratories for post-graduate students, lecture room, and museum. One entire floor is devoted to chemical studies, another to bacteriology, and a third to histology. Under a contract which the Tanners' Council has with the University the building is to be

FIG. 9. — Tanners' Research Laboratories. University of Cincinnati.

devoted to leather research exclusively so long as a specified sum is spent there each year. As a matter of fact the leather industry is spending six times the required sum on basic tanning research. No " hack " work or special problems of a particular contributing corporation are considered, so that work being done there is strictly of a fundamental character. Already laws worked out relative to curing of raw stock, soaking and initial tanning processes have repaid many times the expenditure on the part of the tanners.

In 1927 the Tanners' Council completed details for establishing a Foundation which is to handle bequests and gifts, the income from which is to be used to perpetuate the research work at Cincinnati.

Practical Instruction in Leather Manufacture. The leather industry is also very fortunate in having available a working

arrangement with Pratt Institute, Brooklyn, N. Y., where men are given a very thorough training in the technical and practical aspects of this industry. The graduates from this course, which has now been in operation for over twenty years, occupy responsible positions ranging from foremen, chemists, salesmen and superintendents to managers and owners of plants. The number of these graduates is about two hundred, and they are located in every section of the country as well as in many foreign lands. These men with their technical training together with their appreciation of the value of scientific research and chemical control have been no small factor in bringing the leather industry of this country up to its present high degree of efficiency.

CHAPTER XIII

THE AMERICAN MEAT-PACKING INDUSTRY

By Rudolf A. Clemen[1]

The American Meat-Packing Industry as it exists today has grown up since the Civil War. In 1865 every town or city in the country had its own slaughterhouse. For example, New York had more than 200, and what is now Fifth Avenue was often encumbered by large droves of cattle. Stockyards stood on land in Manhattan that now is the site for some of the finest clubs, hotels, and retail stores in the metropolis.

The growth of the packing business to one of the greatest of the basic industries of the country has paralleled the development of other large American undertakings; for instance, before the Civil War, such agencies of everyday business as transcontinental railways, European cables, telephones, electric lights, and street cars did not exist. Skyscrapers, million-dollar hotels, and automobiles were far in the future. Flying machines, wireless, and radio were beyond the realm of imagination. Safety razors, pneumatic cleaners, and a thousand and one other devices that add comfort and convenience to our modern life had not then taken shape in the inventor's brain.

The modern American meat-packing industry touches the lives of everyone in the United States in a very intimate way. On the one hand it draws its raw material from over six million farmers, each one of whom produces some livestock. On the other hand, the meat-packing industry sells meat and other food products to every person in this country. For everybody except a very few vegetarians eats meat and its kindred products.

However, the packing industry is not the largest industry in this country, measured by some other standards. Measured by sales, the automobile and iron and steel industries are greater, and, meas-

[1] Assistant Director Armour's Livestock Bureau.

ured by the amount of capital, employees, and number of wage earners, it is exceeded by the iron and steel, cotton goods, foundries and machine, and automobile industries. For the meat-packing business employs only about 250,000 workers.

Special Characteristics of Meat Packing. The packing industry has a very different manufacturing process from most other industries. Instead of taking a lot of raw materials, assembling them and fitting them together into a finished product, the packing industry takes a fairly compound unit — steer, hog, or sheep — and breaks it down into many parts. It is a disassembling industry, and outside of its by-product operations does not carry on much so-called manufacturing processing. Again, because of the nature of his business the packer pays 85 cents for his raw material out of every dollar received for his product. In other words, he does not add as great a value through his processing as do some other businesses.

However, the packing business is not at all simple from another, and more important, point of view. The purpose of the packing business is first of all to supply meat foods for this nation and where there is a surplus, for other peoples. To distribute such meat foods nationally and internationally calls for great skill in organization, so that there will be an ample and proper supply at every point within this country and others. This work requires careful study and accurate analysis of the widely differing demands for meat foods in various sections of the United States. No better picture of the problems or the nature of this business can be given than by a short survey of the variations in demand for beef, mutton, lamb, and all pork products.

Satisfying Varied Meat Demands. The kind of beef or pork most desirable for New England markets does not find a ready sale in the Southern States. Beef slaughtered on the Pacific Coast can be marketed only with difficulty on the North Atlantic. Generally speaking, the beef trade is based upon New York and New England because they are the centers of our densest population. New York, Jersey City, and the adjacent regions take all grades and classes of beef. Downtown houses in New York City handle a varied assortment, mostly weighty, for the large shops and the great hotel and restaurant supply trade. Such houses handle almost every kind of beef, except yearling. The Hudson River territory to the north of New York demands a greater

proportion of medium to choice carcasses with lighter weights, while the Long Island and Harlem sections of the city constantly demand the best light-weight carcasses available, predominantly yearlings. Philadelphia absorbs a general assortment like New York, taking all grades from plain to choice, but Philadelphia price levels usually run lower than New York, except on the good choice carcasses.

In New York there is another factor affecting distribution of beef. There are more orthodox Jews in New York City than in any other great consuming center, and orthodox Jews require kosher beef. This is beef which has been killed in a special manner by a rabbi, according to the regulations laid down in the Mosaic law. Under ordinary conditions this kosher beef must be in the hands of the consumer within 72 hours after slaughter. For this reason, Western-killed beef will not do because it ordinarily takes a beef train four days to move from Chicago to New York. This fact accounts for numerous slaughtering plants adjacent to New York which would not otherwise be there. Many of the corn-fed steers from the West are shipped alive to New York to be koshered and these are very high-grade meat animals, for the Jewish trade demands prime meat. Naturally, kosher beef is somewhat higher in price than other beef.

In the New England trade Boston is the hub. It is a market for heavy beef. Carcasses for the Boston market must be strong and well finished with the steer beef running from 800 lbs. up. However, the southern sections of New England usually vary from the northern and western ones in demanding lighter weights. Indeed, the farther south one goes along the eastern seaboard of the United States, the lighter the carcasses demanded. Not only lightness but leanness in beef best suit the consumer of old Dixie.

The Middle West states consume the fair to medium grades with more fed cattle than are included in the South or West. The most desirable carcasses for this market weigh from 400 lbs. to 600 lbs. The principal cities of this region — Chicago, Milwaukee, St. Louis, Kansas City, Omaha, with their adjacent consuming territories — are relatively uniform in their demand. All classes of beef are consumed, but principally light butcher cattle are desired. An interesting vagary of demand is illustrated in the twin cities, Minneapolis and St. Paul. Minneapolis demands

more fed cattle than St. Paul and maintains a more active market, but Minneapolis cattle weigh a little less than St. Paul cattle. Other illustrations might be drawn from various sections, but the examples given indicate the general problem which confronts the packer in distributing meat.

These distribution problems are not confined to beef, however, but apply to the lamb and mutton trade, and to pork as well. For example, before the Great War the South and East were the best outlet for the large dry salt bellies to be sold to the negro trade, while the white trade desired light bacon with 4 to 6 lb. bellies in greatest demand. New England asked for the same mild-cured bacon, but was willing to use ten to twelve and twelve to fourteen pound bellies, providing they were solidly meated and of good quality. Hotel and restaurant trade desires pork loins and hams weighing about 10 lbs., while shop and family trade insists that the same cuts of meat must weigh less.

Great variations in demand occur in the case of sausage. The large sale of quality sausage, both fresh and dry, is in the big cities. The most important outlet for the least expensive grades of sausage occurs in the South and Southwest. Dry sausage is consumed in proportionately greater amounts in metropolitan centers than in the rural districts, while the condition is reversed for fresh sausage. Each foreign nationality in the United States has its own particular favorites among the many varieties of sausage produced, and the packer must meet these widely different demands in particular sections of the country.

This survey of variations in demand for meat products shows clearly that the slaughtering of live animals and dressing and shipping of carcasses are the easiest part of the business. The difficult and more complicated part is that of finding a market.

Many people have a rather erroneous idea about our meat consumption. They think that individual meat consumption has been declining and is continuing to decline. This idea is based upon evidence from hotels and restaurant bills of fare in Colonial days and references to home menus, which indicate that 75 years ago we were eating a great deal more meat. It is true that the average American eats about 10 lbs. less beef and 13 lbs. less pork annually than his ancestor did in 1830, and a large part of the decrease took place between 1900 and the period of the World War. Since 1917, however, there has been a gain of 20 lbs. per

person, for while each American ate only 134 lbs. of meat in 1917, in 1926 he ate approximately 154 lbs.

The packing industry derives its raw material, of course, from the livestock producers of this country, and in order to understand the development of the packing business it is necessary to make a brief survey of the progress of livestock raising. By the Civil War it was clear that the Middle West was the finest feeding ground for livestock in the world. From 1865 to 1895 there were developed, in the states farther west, the great cattle ranges over which a glamour has been cast in song and story. The cattle were driven over the famous trails by cowboys from Texas to Montana, and there was evolved a great surplus supply of cattle ready for the demands of the consuming East, which was rapidly growing as an industrial center. The rapid building of railroads, east and west, made it more and more possible to bring live animals to the newly built packing plants, located in a band of territory north and south from St. Paul to the Gulf of Mexico, where they were slaughtered and their products shipped east to feed the population in our large cities.

Creators of Modern Packing Industry. About 1870 various factors began to work together to make possible our present packing industry. Before the Civil War, when there was no refrigeration available, meat packing had been practically confined to pork. It was not until ways were found to market fresh beef and mutton, as well as cured and fresh pork, that the foundation of the modern packing industry was firmly established. The first step in creating the modern packing industry was the work of certain outstanding men who, visualizing the great future of the business, particularly in Chicago, founded the businesses which have become the great packing companies of today.

There were two groups of these men: first, those who, having had experience in the packing business in Ireland, Germany, or other European countries, came to the United States and established plants to engage primarily in the export trade; second, native Americans who foresaw the possibilities in the development of the livestock and meat industry, and built up important businesses in Chicago, and other packing centers. Cordukes, Sinclair, Morrell, and Kingan were important among this group of packers. Jacob Dold came to this country from Germany in 1848, and founded the Dold Packing Company at Buffalo, New York.

Although he began before the Civil War, his business did not have its real development until after that time.

An entirely different group of packers began business in the Middle West. Among these were John Plankinton, P. D. Armour, G. H. Hammond, Nelson Morris, G. F. Swift, and Michael Cudahy. It is impossible within the space of this article to discuss the lives of these men, or to do more than mention their work in creating the modern packing industry. It is significant that John Plankinton, the first of these men, began his business at Milwaukee in 1844. By the time of the Civil War, Plankinton had developed one of the largest businesses in the United States. It was during the Civil War that he took P. D. Armour into partnership. The firm of Plankinton and Armour enjoyed a phenomenal growth and became the most important in the country before 1870. They were chiefly engaged in pork operation and killed beef only for local consumption. Their products were marketed throughout the United States, and they also had a large export business.

Armour saw, however, that the possibilities of Chicago as a livestock center were greater than those of Milwaukee. Consequently, while still a partner of Plankinton, he established a separate plant in Chicago, by forming a partnership with two of his brothers in 1868. Armour himself did not come to Chicago until 1875. The partnership with Plankinton continued for a number of years, but finally the entire business became consolidated under the name of Armour and Company.

Another of the pioneer packers, Nelson Morris, came to Chicago in 1859. He became one of the largest cattle dealers in the "yards," and built the first packing plant located near the present Union Stock Yards. Morris was responsible for the establishment of the United States export trade in live cattle, and as early as 1868 had made the first successful shipments to England.

Armour and Morris had both been in business in Chicago for a number of years, competing with each other for dominance in the trade, when another of the great pioneers of the packing industry came to Chicago. This was G. F. Swift, who arrived in 1875. Swift was a New England butcher who had realized that the future of the livestock and meat industry lay in the West. Engaging first in the meat business, he had later become interested in buying cattle to be slaughtered by his firm in Boston. Consequently, in buying cattle he had moved west, first to Albany

and then to Buffalo, but he saw that the real development was occurring in Chicago. As a result he dissolved his partnership in a large retail meat business in Boston and became a cattle buyer in the Chicago yards in 1875. By 1877, G. F. Swift had established a packing plant, but unlike Armour and Morris, Swift did not turn his attention to pork packing, but to the problem of marketing beef. It was Swift who demonstrated that fresh beef could be marketed successfully in distant markets.

FIG. 1.—A view of the Hog Section in a Public Stockyard.

It should be remembered that many others were engaged in meat packing during this period. A few of these men built businesses that endured, but most of them dropped by the wayside because, unlike Armour, Morris, Swift, and their associates, they did not keep up with the march of progress in the industry. Several men who were associated with those already mentioned during the seventies and eighties in Chicago later established their own business. Perhaps the most important of these men was Michael Cudahy, a right-hand man in the Armour organization, who founded the Cudahy Packing Company in 1890.

Other factors in the development of the industry were the perfection of refrigeration methods, the adaptation of these to transportation, and other mechanical and scientific innovations in the

actual processing of meat products. These factors revolutionized meat packing between 1870 and 1900. Of them, the most fundamental was artificial refrigeration. Before the refrigeration period meats were preserved by salt and other curing materials and the market area over which fresh meats could be distributed was very small. Nowadays, artificial refrigeration enables us to market fresh meats everywhere in the civilized world. This refrigeration is applied not only to the "coolers" in packing plants and cold-storage warehouses, but also to refrigerator cars and refrigerated steamships.

Today many important mechanical devices add greatly to the efficiency of meat packing. For example, it was always a tiresome job to scrape hog hair from hogs by hand. Now, however, there are different kinds of mechanical hog-scraping apparatus which do the work more efficiently, with less labor and cost. Another invention was the endless-chain system, or overhead conveyor system, by which the animals are carried along before the workmen at a uniform speed. This endless chain system has been installed in many other industries since it was first used in meat-packing plants. It has made possible the minute division of labor and results in an immense saving in labor costs. The rendering of lard has been improved by mechanical inventions, and the democratic sausage is now made by all kinds of machines which do the work much quicker and in more sanitary fashion than of old.

Functions of Different Types of Packers. This modern packing business is carried on in the United States by packers of three different kinds:

1. The so-called large packers, now four in number — Swift and Company, Armour and Company, Wilson and Company, and the Cudahy Packing Company.

2. *a.* Medium-sized packers, interstate packers or national packers, some of them doing an annual business of from 10 to more than 50 million dollars. In 1921, there were 266 establishments, the value of whose products exceed one billion dollars.

b. Small local packers doing a business of not more than one million dollars a year. The local packer may at times do an interstate business when he has an oversupply of certain products such as lard or salt pork, and for this reason will have Federal inspection, but he draws his livestock largely from near-by communities and markets and sells the great bulk of his products locally.

3. Small town and country butchers who can scarcely be called packers, but who slaughter animals at certain seasons of the year. The value of sales of these establishments is very small.

Packing companies may also be classed as local uninspected, inspected local and regional, and national packers. National packers would include roughly those plants in classes 1 and 2; inspected local and regional packers would include the small plants of class 2. Uninspected local packers would correspond to class 3. Of course, in addition to these three classes of meat producers, there are the farmers themselves who kill animals on the farm.

The large packer came into existence in the United States primarily because of the long-distance service that had to be performed. Approximately two thirds of the livestock is raised west of the Mississippi River and two thirds of the consumers live east of this river. A very large proportion of the population live a thousand miles or more distant from where a large percentage of the livestock is produced. This situation requires a vast organization — first, to assemble animals in sufficient quantity and variety; second, to establish and maintain the organization to sell in distant markets. This organization in the domestic market requires the operation of branch houses, car routes, and specialty selling organizations, and in the foreign market, branches, agencies, and brokerage arrangements.

The large packer also has certain advantages from a manufacturing standpoint, such as more complete utilization of by-products, a more minute division of labor, the purchase of supplies in large quantities, and other advantages which accrue to large-scale industry. Additional operating and overhead expenses may largely counterbalance these advantages. It is probably safe to say that the strength of the large packer lies mainly in his ability to sell products in distant markets. In England, where there is fairly uniform distribution of livestock and human population, meat packing is done mainly by a system of small-sized plants that conduct chiefly a local business.

Livestock is not sent to market in a steady stream; instead, the flow varies from day to day, week to week, month to month, and season to season. The seasonal variation in the receipts of livestock makes necessary the carrying of certain products from the seasons of heavy marketings to seasons of light marketings.

Since beef and mutton must be consumed principally while fresh, the job of adjusting cattle slaughter to beef consumption is accomplished without any great storage service. The situation with regard to pork is altogether different.

Although the large packer is undoubtedly in a favorable position to equalize distribution by carrying pork products from periods of plenty to periods of scarcity, it should be recognized that this is a supplementary rather than a major function of his large-scale business. The necessity of storing products would not of itself

Fig. 2. — View of Dressed Beef in a Packing Plant Cooler.

justify the existence of large packing plants. If other conditions were favorable, a system of small-sized plants would undoubtedly find that this storage problem would be solved by small packers and outside risk-takers in very much the same manner as the storage of eggs and butter is handled at the present time.

Great Variety of By-Products. Perhaps the most widely known characteristic of the packing industry is its manufacture of by-products. This is tremendously important, because it very often happens that the sale of by-products makes possible the payment of dividends in spite of losses sustained in the sale of fresh beef and pork. Due to the splendid work of American chemists, the pack-

ing industry has been able to develop means of utilizing nearly all parts of the animals processed in its plant. However, many erroneous ideas are held by the public regarding the meaning of the term by-product. This confusion is added to by the fact that many of the products of the packing industry require elaborate and expensive processing after they leave the packer's hands. Indeed, some of them are but the basis for important outside industries. For example, tanning, glue, gelatin, and animal-feed industries are all important businesses, which rely upon packing-house by-products for their raw material. The meat packer considers everything a by-product except dressed meat.

It is impossible to give a full list of the by-products of meat packing, but a few illustrations will suffice. Blood is processed in such a way that an edible serum albumen is made and can be used by the bakery trade in almost every case where white of egg is called for. Again, by drying, grinding, and screening, a very fine, clean dark powder, called blood meal, is produced which is widely used as a supplementary feed for poultry, calves, colts, and lambs. Dried blood is also used for fertilizer.

Hoofs and horns are softened by steam, pressed into flat plates, and with the aid of stamping machines are manufactured into combs, buttons, hairpins, umbrella handles, napkin rings, tobacco boxes, and buckles. Shin bones are likewise made into knife and razor handles, pipe stems, dice, chess men, electrical bushings, crochet needles, flat buttons, collar buttons, washers, bone rings for nursing bottles, and many other articles. Probably the most important by-product is the hide, which is of course subjected to a tanning process and made into the thousand and one articles of leather which enter into our everyday trade. The hair from cattle and hogs is used as a binder in house plaster, for stuffing horse collars and furniture; and the fine hairs from the ears of cattle are made into hair brushes for fine artistic work. Gall stones are shipped to Japan, where they are used as charms to bring good luck. The intestines of livestock are used for sausage casings in general, but certain of the finer grades are cured, dried, and used as caps for perfume bottles. Again, intestines from sheep are used for music strings and surgical ligatures.

Among the more recent developments in by-products can be mentioned those used in medicine — the so-called pharmaceuticals. Some fifty preparations are now made from fresh glands and mem-

branes of livestock. Among the important medicinal products are pepsin, pancreatin, thyroid extract, benzoinated lard, suprarenalin, and pituitary liquid. These are made from glands and membranes of hogs, cows, and sheep, and among them are some of the most important therapeutic agents. Recently, a cure for diabetes has been developed from the pancreas of hogs, viz., insulin, which is likely to be of vast benefit to mankind.

Some of the other by-products of the packing industry are soap and glue and gelatin, which are made on a very large scale and whose importance is well known without further discussion.

Source of Livestock for Packers. Most of the livestock of this country is sold by the producers at the public livestock markets, of which there are 67 officially recognized by the U. S. Department of Agriculture. Of these, Chicago, Kansas City, Omaha, East St. Louis, St. Paul, Ft. Worth, Sioux City, St. Joseph, Denver, Wichita, Indianapolis, and Oklahoma City are the most important, and handle about 65 per cent of the total business. At the markets, all the organizations and facilities for the livestock trade are present, such as a stockyard company, a transportation company, commission houses, packing companies, livestock buyers and speculators, banks, and market newspapers.

The stockyard company owns the yards and all the equipment for unloading and sheltering the livestock, also facilities for feeding and watering stock. Its function is really to provide a hotel for livestock. The company derives its income from the sale of feed and a small yardage fee. The transportation company at the market owns the switch tracks leading from the main railroad lines into the yards, and also the engines which handle the livestock trains to and from the loading chutes. Its service comprises the assembly of the livestock cars from all railroads supplying the market and the delivery to these railroads of outgoing shipments. Its pay is received through switching charges at so much per car.

The commission companies which act as representatives of the sellers are organized in a livestock exchange building. These commission firms have allotted to them by the stockyard company certain groups of pens in the market where they bring the stock consigned to them and offer it for sale. No rent is paid for these pens other than the yardage fee paid by the livestock shipper. The commission firms maintain salesmen who ordinarily specialize in certain classes of livestock, assuring a high degree of efficiency.

The grower of the livestock may himself offer his stock for sale, but because of unfamiliarity with market conditions would be likely to get less for his stock than the commission house salesman procures. For its service, the commission company is entitled to a fee according to detailed rules. The rates at Chicago are approximately $17 for a straight carload of cattle or calves, and $14 for hogs or sheep in single-deck cars and $20 for double-deck cars. Since the War, coöperative selling organizations have been established which return to the producer owners any profit secured after the cost of service has been paid for.

At all markets, local packers have erected plants from which they supply the neighboring territory with meat. At the big markets, where there is a surplus of livestock in proportion to the local needs, the national packers have located their plants, in which they process livestock, ship the products to all parts of the country, and also abroad, and store other products for the use during seasons of short livestock supply.

Besides the buyers from the local and national packing houses, so-called order buyers are operating on the market. These men buy mostly on orders for eastern packers, and ship the livestock to the seaboard for slaughter. The traders or speculators buy and sell within the market wherever they expect a chance of profit, and especially buy mixed carloads, sort these, and make up new loads of uniform grades.

Stockyards banks provide facilities for the transactions through commission man and packer which enable the shipper to carry cash home with him if he so desires, or to obtain transfers of credit to his local banking institution. Market papers inform the shipper as to receipts, prices, and trade conditions. In recent years the government has established a service at the larger markets providing regular quotations and other information. The sanitary conditions are also under the control of government officials.

Methods of Buying Livestock at Central Markets. When the livestock cars have been switched from the main railroad lines into the yards, by the terminal railroad, they are unloaded at the chutes by representatives of the stockyard company, who receive the waybills and take over the responsibility for the stock. The animals are brought to the pens of the commission firm to which they are consigned and locked in each pen until the commission firm acknowledges receipt of the stock by requesting the opening

of the padlock. For the information of the commission men, the bills of lading are called and posted at the receiving office or chute house. The commission men may also meet the trains and take over their stock from the stockyard company at the chutes.

The commission man orders the feed for the stock and offers the stock for sale. It is customary for only one buyer at a time to negotiate with the salesman, and the deal is completed by a word or nod of the head, no written contract being prepared. The bidding is on the basis of price per hundred pounds live weight, and immediately after the purchase the stock is driven to the scale houses operated by the stockyard company. The total price is determined on the basis of the weight stamped on the scale ticket. When the stock leaves the scale house, the responsibility of the commission man ends, and the stock is in the possession of the buyer, who ordinarily drives it to his own pens where he can keep it until it is ready for slaughter or transportation out of the market.

All sales of stock are cash and the same afternoon on which the stock is sold commission firms make up their accounts with the customers. From the amount actually received for the stock is subtracted the amount of the railroad transportation bill, which the commission man refunds the stockyard company to meet the bill it settled on receipt of cars. Yardage fee, feed bill, insurance fee, and commission fees are also subtracted, as well as occasional special fees for organization work agreed to by the shipper.

Government Market Activities. The nature of the livestock and meat business, and its relation to the general welfare and health of the people, have proved of such importance that governmental services of various sorts have been established. These activities fall under the administration of the U. S. Department of Agriculture, but are conducted by three different institutions — The Bureau of Animal Industry, the Bureau of Agricultural Economics, and the Packers and Stockyards Administration. The first is responsible for the veterinary inspection at the yards and in the packing plants; the second performs the market news service; and the third administers the regulations dealing with packers and stockyards control.

The Bureau of Animal Industry has charge of the veterinary inspection of livestock and meats. All livestock entering public markets pass by an inspector, all animals suspected of infectious disease being removed and quarantined until they can be killed

under special supervision. At the inspected packing houses the live animals once more pass a government inspector. During the dressing of the carcasses comes a post mortem examination at which internal organs of the animals are examined for tuberculosis and other diseases which may make them unfit for human food. According to the findings the carcasses are stamped — " U. S. Inspected and Passed," " Passed for Sterilization," or " Condemned." The second group may be sold after proper cooking under government control. The third group is consigned to the grease vat and sold as inedible grease or fertilizer. Also the general hygienic conditions in the packing houses, the treatment of the meats in storage and through the various processes are supervised by government inspectors who insure the public that all meat products coming from an inspected plant are wholesome and fit for human consumption.

The Division of Marketing Livestock, Meats, and Wool, of the Bureau of Agricultural Economics, has representatives at the important livestock markets in Chicago and the big eastern cities. The division maintains a highly efficient market news service by means of a network of leased telegraph wires. The data collected are published in mimeograph and printed form and comprise several daily market reports and advance estimates on livestock receipts for the following day, also weekly detailed reports on the twelve leading livestock markets, and monthly reports on sixty-seven public markets. Daily reports of wholesale meat prices are also issued.

The Division of Crops and Livestock Estimates publishes information concerning the status and prospects of livestock production. This information is prepared in the form of regular reports, of which some of the more important are: the annual estimate of livestock population (January 1); the estimate of number of brood sows on farms (April 1); the condition of livestock (May 1); the hog surveys through rural mail carriers (June 1 and December 1); estimate of calf and lamb crops in the range states (July 1); estimates of stock hogs on farms (September 15); number of cattle on feed in the cornbelt states and the number of lambs in the principal feeding areas of the west (December and January); also other reports covering special areas.

The Packers and Stockyards Administration functions directly under the Chief of the Bureau of Animal Industry who reports

to the Secretary of Agriculture. The organization comprises separate divisions dealing with the livestock commission companies, the stockyard companies, and the packers. The activities of the Stockyards Administration are regulatory and are intended to insure and enforce fair trade practices and free competitive conditions. The administration also determines all fees and

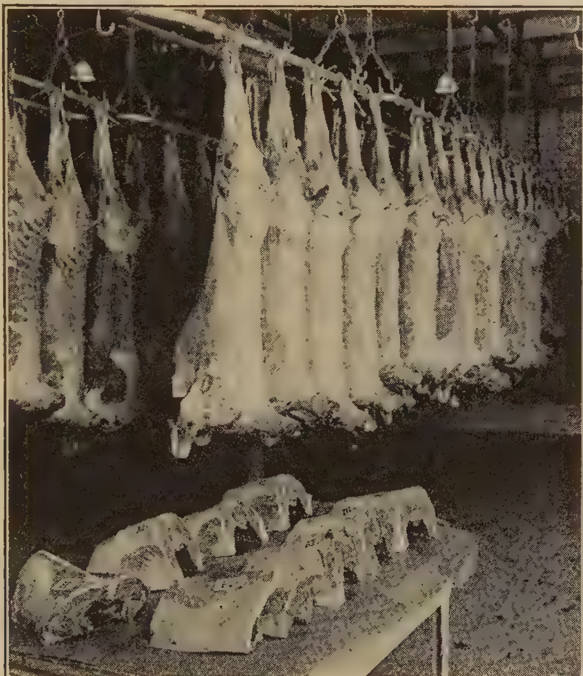


FIG. 3. — Lamb Carcass and Cuts in Wholesale Market.

charges collected from the producers by the commission firms and stockyards companies.

Wholesale Marketing of Meat Products. The refrigerator car is the backbone of the entire system of wholesaling meats. It was first constructed in the seventies and marked an epoch in the history of the meat business.

The modern refrigerator car is quite an expensive equipment, costing about $3000. In fact, it was the lack of sufficient capital on the part of the railroads which caused the packers to build their own car equipment. In each end of the car four tanks are located

which are filled with a mixture of ice and salt and over which the air circulates for cooling. The car itself is insulated so that the meat, hanging from the roof of the car or placed in boxes on the floor, may be kept at a uniformly low temperature, so that it will arrive at the point of destination in the same condition as when it was placed in the car.

The packers who own their refrigerator cars lease them to the railroads on a mileage basis and in turn pay the railroads the ordinary freight charges for transporting the meat. These charges are fixed by the Interstate Commerce Commission and require a minimum weight of product in each haul. These minima are 21,000 pounds for fresh meat and 30,000 pounds for cured products. The railroads maintain icing stations at intervals of 200 or 300 miles along the road and charge the packers for re-filling the ice tanks when necessary during the haul.

The ideal way of wholesaling meat outside of the immediate neighborhood packing house is through refrigerated branch houses. However, as these require a rather big investment, they can only be established in towns or territories with a population sufficient to develop a considerable volume of trade. The majority of them are therefore located in the industrial states of the East or in the deficient-producing states of the South. A typical branch house includes offices, meat coolers, and frequently equipment for curing and smoking pork products and for making sausages.

Groups of twenty to thirty branch houses are under the direction of a superintendent who is the sales director of the territory and also the business manager of the physical properties and equipment, the value of which often amounts to several million dollars. Each branch house is headed by a manager. The branch house has technical help where some processing of meats is performed; in fact, when better prices can be received for freshly packaged or processed products a part of the ordinary activity of the packing plant is frequently transferred to the branch house. For the sale of packing-house products a staff of salesmen is employed, most of whom do general work, but a few are also specialty salesmen devoting their efforts to the sales of particular products like canned meats, soap, etc. The salesman solicits orders by calling regularly on customers or by using the telephone. The cost of branch-house service is considerable and amounts on the average to over a dollar per hundred weight of product sold.

In towns or districts where there is not a sufficiently large market to establish a permanent branch house, the trade is covered by car routes. These are either managed from the packing plant at which they start or from the branch house to which they go, after having made intermediate stops en route. In the latter case the branch house takes the products remaining in the car after the deliveries have been made at the route points, thereby making full loading possible. The sales for car routes are made before the car starts by salesmen who travel along the route and solicit orders to be filled by the car, which covers the territory once or twice a week. The unloading is done by the train crew, no special attendant traveling with the car.

Packing houses not having their own branch-house systems or wanting to do business in districts where it would not pay them to maintain such houses or send route cars regularly, consign products to local brokers who possess the necessary equipment for handling meat products. The brokers receive regular price quotations from the packers and sell the products on the basis of a commission ranging from 1 to 5 per cent according to the nature of the product. This way of wholesaling meats is, however, rapidly diminishing in importance.

Certain firms operate on much the same plan as brokers, in so far as the physical distribution of product is concerned; but instead of operating on a commission basis, actually buy and sell goods. Hotel and institutional supply houses come under this class, as do certain large export houses. Jobbers often act as supply agents for a number of retail stores in a given locality, buying the grade and assortment of products they find each retailer needs. Such jobbers usually are limited by their customers in the quantities they buy, but use their own judgment on prices, maintaining their trade by supplying the retailer with meats he can move at a profit.

Foreign Marketing of Meats. While the founding of the live-stock industry in this country had for its purpose primarily the supplying of the settlements along the Atlantic seaboard with meat and other animal products, the export trade became the factor which made it develop to such vast dimensions. All through colonial days the revenue from the sale of salt pork and barreled beef in the West Indies constituted an important source of income for the colonies. Similarly, the agricultural migration, which resulted in the settling of the Middle and Far West, and the devel-

opment of transportation facilities from the interior of the country to the seaboard, was largely the response to the increasing demand of western Europe for supplies of grain and meat to feed its growing industrial population.

The transition to the twentieth century marked a change in this development, since the export of agricultural products began to decline yearly from that time until the beginning of the World War, when beef required a net import to meet our needs. The reasons for this significant falling off of our export trade in meat products were threefold — first, several European countries adopted definite policies to make them less dependent on foreign supplies; second, other surplus-producing countries, like the South American republics, Canada, and Australia, developed a strong competition against our products, being able to produce grain and beef cheaper than it could be done in this country; and third, this country developed flourishing industries to which a steadily increasing proportion of the farm production became diverted. More and more the object of American agriculture came to be the supply of our own industrial population with the farm products necessary for food and clothing.

The World War upset all natural developments and trends and forced the belligerent parties to secure as much food products as possible at any price and wherever it was available. American agriculture again responded to the call for food products from European powers which could not supply their armies and home population from the scant output of their own reduced production. Since 1919–20, however, exports of meat products have approximately returned to pre-War bases, as far as volume is concerned. Nevertheless the disturbed economic conditions in Europe have made this trade far less profitable than in the pre-War period. Over one fifth of the inspected production of the country is exported, in fact, over one-half of our inspected lard production is often sold abroad. There is a real need of a foreign outlet for pork products, at least so long as domestic consumption does not approximately measure up to production. In order to dispose of the large quantities of pork and lard which could not be sold on the domestic market without the most serious effect on prices of provisions, as well as of live hogs, a number of packing companies have developed extensive organizations for the selling of their products in foreign countries.

There are two main geographic groups of such foreign agencies. First, houses and agents are distributed densely over the West Indies and northern and western coast of South America. Although these agencies are numerous, the trade in this area is very limited in quantity and comprises mostly lard and lard compounds besides some barreled beef. In Brazil, Uruguay, Argentina, and Paraguay are the South American plants belonging to Armour and Company. These plants do mostly export trade of beef to

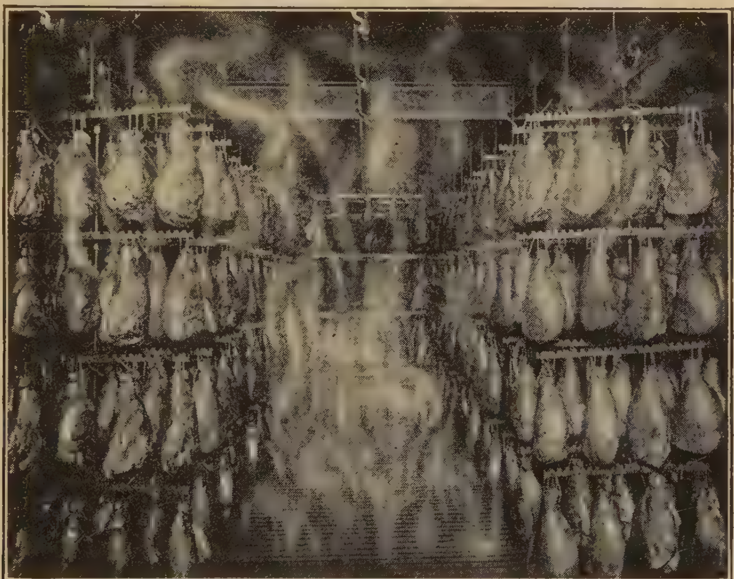


FIG. 4. — Hams in the Process of Being Smoked.

Europe, but also some local business. The other big group of foreign agencies covers the western part of Europe. Great Britain offers the largest and most attractive market for the higher quality pork products, like bacon and hams, but takes also considerable quantities of lard. Continental Europe, on the other hand, is a heavy buyer of dry salt products and lard.

As already mentioned, the American export trade in meats has virtually been limited to pork products — bacon, hams, dry salt pork, and lard. With respect to the three latter products, the trade of this country is practically unchallenged on the international markets, no other countries having appreciable quantities

available for export. In the bacon trade, however, American products are involved in a most serious competition, the nature and problems of which are of considerable importance to American agriculture. The international bacon market is, for all practical purposes, identical with the British market. No other country imports bacon in such quantities as to influence the trade as a whole.

At the present time, with reference to origin, the English bacon supply is largely made up of five kinds — Domestic, Irish, Danish, Canadian, and American. Previous to the World War there was a fairly constant relation between the quantities imported from the various countries, Denmark, however, getting more and more in the lead, and the volume from other countries, mostly European, also increasing. This condition was entirely upset during the years of war. Due to the blockade, Denmark dropped entirely out of the British market. The United States and Canada thereby got a chance to capture the entire business, and also to enjoy the increased volume of trade caused by the demand for the armies and the decline in home production in England. The post-War period has been characterized by the re-taking of the market by the Danes. The quantities sold by this country and Canada have been proportionately reduced, so that the volume of business done by the competing countries is now approximately the same as before the War.

In this country, the domestic market has always been the first consideration, and this fact, in connection with the special agricultural conditions in the cornbelt, has resulted in no attempt being made until recently to incorporate the production of English-type bacon in the American hog-breeding program. What this country has to offer in England is therefore the surplus of the domestic production in such selections as will most nearly suit the trade.

Financing the Packing Industry. Both the international and national distribution of meat and packing-house products requires a great amount of money. While every packer, like any other business man, has certain funds at his disposal, through capitalization and otherwise, he has to rely on banking institutions for large loans enabling him to conduct his business efficiently and smoothly, because its very nature calls for cash payments to a greater degree than many other kinds of business. Financing the packing business is the consummation of a trade between the producers of livestock and the consumers of meat. The packer, assisted by

the banker, makes it possible for the consumer to buy the meat animal which the stocksman has raised. In this the packer takes a financial risk, for he acquires the title to the livestock and pays cash for it in whatever quantities it comes. However, when he has borrowed money and bought livestock, *e.g.*, hogs, he cannot get his money out without processing it. For consumers do not eat hogs; they eat pork. To convert hogs into pork and other pork products ready for sale means more money. Plant equipment and operations are required. The man who hoists the hog, the man who slaughters it, the men who dress it, the men who push it or cut it or pack it or make out bills for it or write letters about it — all these and others have to be paid. The packer must borrow enough to meet his payroll and to keep his plant in good order as part of the process of turning the hog into pork and selling it.

When, finally, the packer has turned his hog into pork, he finds that only the fresh pork can be sold immediately. Other cuts must be put into cure for one, two, or perhaps three months. This means spending more money; wages to the man who salts them, to the man who lifts them out of one vat into another, to the man who examines them to see whether they are cured, to the accountant who keeps track of them, to the auditor who changes their value on the books as the market changes, to many others who contribute to the final result. There are also disbursements for many things besides wages. All of these expenses must be financed until the products can be sold. At last the cured meats are offered on the market. But the market has been oversupplied; the packer is forced to look for buyers outside of the day-to-day domestic demand.

An Englishman finally buys the bacon, a man in Holland takes the lard, a Boston retailer purchases the hams, a member of the Board of Trade contracts for the fat back, and, in the course of a month or two, receipts of hogs become light and the packer takes the shoulders out of cold storage and sells them. If he is lucky, he gets his money back and a small profit in addition. He must repay with interest all he has borrowed, pay all expenses not already met, and, if possible, give the stockholders a fair dividend on their investment. He has made it possible with the help of the banker, the retailer, and others for the farmer to sell his hog to the consumer. Multiply the operations just described by the vast

number of hogs slaughtered, and of cattle, and of sheep, and of calves, and you get some idea of the magnitude of packing-house finance.

This description of the packer's needs in financing indicate that the packing industry is pretty much on a cash basis. The fact that livestock is paid for on the day it is bought, that payrolls are met weekly, that purchases of supplies are in most cases paid for ten days after receipt of invoice, in order to take advantage of cash discount, makes it necessary for the packer in turn to sell his goods on short-time credit.

Meat packers, of course, utilize their own capital in financing their business. However, beyond this, borrowed capital plays an important rôle in the industry. In a recent year, the amount of capital owned and borrowed and actually invested in meat packing amounted to $1,176,483,643.00, and in the same year the production of beef, pork, lard, and mutton totaled 18,700,000,000 pounds, which is equivalent to approximately 60,000,000 or two thousand carloads daily. In addition, there is always being carried in cold storage a tremendous amount of meats and lard which involve heavy carrying charges. Likewise, the exports of packing-house products run into the hundreds of millions of dollars, all of which must be financed in some manner.

Owing to the fact that livestock is paid for in cash; that it is to the advantage of a packer to discount his bills for purchases of supplies; that it is necessary for him to accumulate supplies of meats in cure and storage; that by-products must be put through manufacturing processes which take considerable time, and then often have to be carried for months before sale is effected — these and other circumstances mean that the packer operates to a large extent on borrowed capital, obtained principally through bonds, debenture notes, bank loans, and commercial paper.

Variations in the financial policy of packing firms and in the efficiency of their management almost equal the number of firms. It is most difficult to say when or for what purpose a packer has occasion to borrow money. A business cannot stand still. It must go either forward or backward. Assuming that a packer is aggressive and desirous of expanding his business, he finds that financing himself entirely out of his earnings is rather slow, and he must go to an investment or banking house to seek funds. When money is plentiful and rates of interest reasonable, it is

sometimes advantageous to do his long-time financing by means of bonds or debenture notes. On the other hand, when there is a shortage of working capital, interest rates are unfavorable to long-time financing.

In general, the packing industry satisfies requirements for commercial paper borrowing, and many packers with well-established credit use it extensively. Both large and small banks make a practice of buying packers' commercial paper at times when they have surplus funds to loan for a short period. The notes are usually turned every three to six months.

The advantage claimed for commercial paper is that through it the borrower can obtain a lower interest rate than is offered by his bank. This is debatable. The principal use that the packer makes of commercial paper is during time of accumulation of product, especially in winter when hog receipts are heavy and pork products have to be put in cure in large quantities and carried three to six months or longer before they are sold. During such a period a packer may have utilized to the full his line of credit with his different banks, in which case he secures his additional funds by disposing of commercial paper in the open market.

The packing industry acquires the largest part of its current borrowed funds from bank loans. According to the size of the business, a packer establishes what is called a line of credit with one, a few, or many commercial banks. This means that an officer of the bank, after a thorough examination of the condition of the company, pledges his word to advance funds within a certain limit set either by the size of the bank or of the borrowing concern, or by the financial condition of the company. In return for this accommodation the bank will require a deposit, ranging from 10 to 20 per cent, on which the borrower receives no interest. Some banks consistently require that the full percentage of the line shall be maintained, or a certain minimum of deposit on a loan, for example, 10 per cent, even though it is not being used, and then require the usual 20 per cent balance when loans are actually made. Another plan is to keep on deposit a rough average percentage of the actual borrowings. The method used depends, among other things, upon local custom, size of the bank, importance of the business, character of its management, and the type of industry.

Financial Organization of National Packers. The national packers who suffered severely during the post-War deflation now

find themselves in a strong financial position as a result of the recent business prosperity. When the World War opened, the packing industry was called upon to supply food products in unprecedented volume. Naturally, with immense sales, profits were large, but plant facilities were increased proportionately and inventories had to be held at figures which would not have been warranted except for national emergency. The packers continued to prosper until 1920, because Europe was still dependent upon this country for a large part of its meat supplies. However, in 1921 profits dropped off rather sharply, and a part of the dividends had to be paid out of undivided profits.

The storm broke in 1921, and by the end of the year all of the national packers were faced with large inventories which had depreciated because of lessened demand. Good business practice required that these losses be written off, and so the large companies showed great deficits. Since that time Wilson and Company has gone through a receivership, Armour and Company has reorganized its finances, Swift and Company has made a slow but steady annual improvement, and the Cudahy Packing Company has shown considerable gains in earnings.

The packing industry at no time has been a business of very large profits compared with other businesses. When the earnings of a corporation run into eight figures in the dollar column, there arises immediately the thought that the margins of profit must be enormous; but on the contrary the percentage of profits and gross sales are exceedingly small, running around 2 cents per dollar of sales. Thus it can be seen that there must be very skillful operation in order to show a profit.

Yet the stockholders in national packing companies have been able to receive a fair return in investment. For example, the present corporation of Armour and Company was formed in 1900, succeeding a previous corporation of the same name which had been in existence for thirty or forty years. On the common stock of $100 par value, dividends as high as 10 per cent were paid in several years, and in 1916 a 400 per cent stock dividend was paid. The difficulties following the War brought about necessity for new financial arrangements and the common stock was changed in 1920 to Class A and Class B, and this was followed by the payment of 4 per cent on Class A shares in 1921, and 8 per cent in 1925. All dividends on the preferred stock of Armour of Illinois, Armour of

Delaware, and North American Provision Company, the two latter being guaranteed by the first-named corporation, have been paid when due.

All of the national packers have developed a good working capital position since the post-War deflation period. This improvement has been brought about for the most part by the cutting down of current liabilities. Swift and Company, for example, in the five years following 1921, reduced its current liabilities by thirteen million dollars, the Cudahy Packing Company's reduction was $7\frac{1}{2}$ million, while Armour and Company's reduction aggregated ninety-three million dollars. The cash situation of the various companies has shown considerable fluctuation, but in 1926 Swift and Company had a cash equivalent to about 34 per cent of all its current liabilities, the Cudahy Packing Company nearly 66 per cent, while Armour and Company's position was somewhat lower than the year before, having indicated 44 per cent.

Though mounting in recent years, the inventories have not been out of line with sales, and indeed have latterly been smaller in proportion to sales. Of the national packers, Armour and Company and Swift and Company turn their inventories about eight times a year, while Cudahy has a little more rapid turnover. Thus far since the War, a fairly constant ratio has been maintained for the working capital and net sales.

It is impossible to discuss all of the details of the funded debts of the national packers, but a short statement may be made regarding their financial structure. Swift and Company has the simplest. Its capital stock consists of but one class of shares, the outstanding amount of which has remained constant at 1,500,000 shares for the last seven years. The earnings of the company have been quite sufficient to take care of its dividend requirements and to strengthen its financial position. Less than one third of Swift and Company's capitalization is in bonds and notes. Armour and Company of Illinois presents a more complicated financial structure. Not only has it outstanding a funded debt of its own and its subsidiaries for which it is liable, but it also has three classes of stock, and guarantees the payment of dividends on two preferred issues of subsidiary properties. Ahead of the Armour of Illinois preferred stock is some $210,000,000 worth of senior securities on which the annual interest charges are seventeen and one half million dollars. Holders of the Class A common

stock are entitled to $2 a year dividends, before any payments can be made on Class B.

While Armour and Company was hit somewhat harder than the other national packers in the deflation of 1921, the intrinsic value of its common shares has been built up in recent years, and it is in better financial condition than at any time since the War.

Labor Conditions in the Packing Industry. Like other large and progressive industries, the meat-packing business has, during the past twenty years, done much to improve working conditions, or, to use an over-worked phrase, "humanized" the industry. Employees have been invited to buy shares of stock in various companies. Medical departments, safety plans, lunch rooms, gymnasiums, and continuation schools have been provided by many of the leading firms. For cases of misfortune and death, benefit associations and pension funds have been set up, which have done much good. One special plan for improving the plant worker's condition in this industry where working hours in the plants fluctuate greatly according to changes in livestock receipts, is that of guaranteed time. This plan provides that regardless of whether a standard number of hours has been worked or not, the hourly worker in the plants is guaranteed pay for that standard number of hours. This working time is guaranteed weekly and not on a daily basis.

In recent years, as a result of war conditions, there have been set up in various packing companies plans of employee representation. A typical plan provides for equal representation of employees and management in consideration of all customs of policy. In each plant there are set up divisional committees and a plant conference board. The number of representatives on the committees and boards are proportional to the number of employees. The plant conference boards and divisional committees may consider and make recommendations on all questions pertaining to employment and working conditions, wages and cost of living, safety and prevention of accidents, health and plant sanitation, hours of labor, education and publications, recreation and athletics, and other matters of mutual interest.

One of the most important matters in the plan is the procedure. Any employee who wishes to bring any matters before the divisional committee, or the plant conference board, may present them to the employment manager either in person or through the precinct

representatives. It shall be his duty, first, to ascertain whether or not the matter has been properly presented through the regular channels to the department superintendent, and if not, he shall see that this is promptly done. After that the matter may be referred to the divisional committees, or conference board, and the employee shall have an opportunity to appear before it and present the case. Any group of employees shall select not more than three spokesmen from their own number to appear before the board of committees.

The conference board or divisional committee may call any employee before them, to give information regarding any matter under consideration. The conference board or divisional committees, or any subcommittees appointed by them for that purpose, may go in a body to any part of the plant to make investigations. After complete investigation and full discussion of any matter under consideration by the divisional committees or conference board, the chairman calls for a vote, which is secret unless otherwise ordered by the board. The employee representatives and the management representatives vote separately. The vote of the majority of the employee representatives is made separately. This is taken as the vote of all and recorded as their unit vote. Similarly, the vote of a majority of the management representatives is taken as the vote of all and recorded as their unit vote. Both the employee representatives and the management representatives have the right to withdraw temporarily from any meeting, for private discussion of any matter under consideration.

When the conference board reaches an agreement on any matter, its recommendation is referred to the superintendent for execution, except that if the superintendent considers it of such importance as to require the attention of the general officers, he immediately refers it to the general superintendent of the company, who, in case he approves the recommendation of the conference board, may order its immediate execution by the superintendent. In any case where the vote in the plant conference board remains a tie, the matter, at the request of either the employee representatives or the management representatives, is then referred to the general superintendent of all plants. He will either within 10 days after the matter has been referred to him, propose a settlement thereof or take it directly to a general conference board. If the settlement proposed by the general superintendent is not satisfactory

to a majority of the employee representatives, and if after a further period of 5 days no agreement has been reached, then the general superintendent may, if he deems it advisable, refer the matter to a general conference board.

Such plans and benefits for employees have done much to stabilize labor conditions in the packing business and enable the packing industry to recover from the depression of 1921 through increased efficiency of employees and their greater interest in their work.

Competition in the Packing Industry. The public conception of the extent of competition and its keenness within the packing industry has been fashioned very largely by critics. On the other hand, little has been provided by its representatives to crystallize a clear picture of the conditions which actually exist. The popular view of current economic affairs is determined largely by the sensational generalizations which find expression in the press. These expressions, however, are usually based on the charges made by individuals or organizations which are assumed to be competent, but which usually prove to be superficial and erroneous. It has been possible for confused viewpoints to be accepted as true, because of the great complexity of the business, the variety of services required of the industry, and the apparently indirect functioning of the law of supply and demand, since the consumer demand is not expressed for livestock (in which form the supply is secured), but for meat, fats, hides, and animal by-products.

The fundamental difficulty in understanding the competitive situation among meat packers has arisen from the different services required in the marketing of livestock and in filling the wants of consumers. All sections of the United States consume some meat, and all sections produce some livestock. However, in the industrial regions the demand far outweighs the supply, and in the producing regions the supply similarly outweighs the demand. This situation provides a logical background for the location of the plants of the local packer in the regions of light supply and large demand, and for the plants of the national packer, dealing in surpluses, in the regions of heavy supply and lighter demand.

The local packer can compete against the national packer because he deals in quicker turnovers, possesses more uniform outlets, distributes his products over narrower areas with lighter transportation costs, and requires less overhead expense in operating. These

factors permit him to reduce operations in the fact of unfavorable markets and to operate heavily when his livestock is cutting out at a profit. The big packer, on the other hand, has the advantage of wider distributive outlets, more perfect utilization of by-products, and sufficient storage capacity to permit more uniform sales throughout the year. This comparative situation between the two types of packers has brought about the keenest degree of competitive conditions within the industry.

Some producers have believed that the packer can or does manipulate the market. This belief has been largely on the lack of adequate demand when there have been heavy gluts in the runs of livestock, or on the supposed desire of the packer to break the prices of livestock to constantly lower levels. Both of these conditions are merely apparent and have very natural explanations. When heavy runs of livestock occur, the channels of trade in meat and meat products become choked and the packer who buys beyond his requirements incurs a tremendous marketing risk. If he does purchase an additional number of head, he must do so at a price commensurate with the risk he is assuming. This risk, however, is not confined to the actual value of the animals he purchases, but includes the extreme probability of a break in the entire market for meats and a reduction in the price level on everything which he and his competitors may previously have purchased. In the case of a small packer, the financial risk, of course, is not great, but in the case of a packer with broad interests, the problem is vital.

CHAPTER XIV

THE LUMBER INDUSTRY

By R. C. Bryant[1]

The Historical Development. Logging and lumber manufacture are among the oldest industries in the United States, having been established more than 300 years ago. "The first settler was the first lumberman," if we regard as such the colonist who felled and prepared timber for the construction of his cabin and who cut wood for domestic fuel; however, we consider that the industry began when sawmills first were erected to supply the needs of the mill owner and his neighbors for sawed products.

One of the first sawmills in this country was erected in southwestern Maine about 1623. The number of mills in this region, and in other sections which were settled contemporaneously, increased rapidly and produced sawed material not only for domestic but likewise for foreign trade, chiefly with the mother country and the West Indies. The colonists also developed some commerce in ship masts, yards, bowsprits, and ship timbers and, in addition, worked the pine forests in the southern coastal plain region for naval stores. Shipbuilding was an important industry in New England, where vessels were constructed not only for the colonists but also for the English, French and Spanish. The two latter peoples often paid for their vessels in rum, molasses, wines, and silks.

The importance of lumber as a commodity to the early settlers is shown by the fact that, in some places, it was accepted in lieu of cash for the payment of taxes.

Lumbering as an industry did not become of great importance until the early part of the nineteenth century. One of the chief centers of development in New England was on the Penobscot River in the vicinity of Bangor, Maine, where the lumber output in 1816 approximated one million board feet. Later the industry spread to the Kennebec and other Maine rivers.

[1] School of Forestry, Yale University.

The first operations in New York State were on the watershed of the Hudson River and its tributaries, where lumber manufacture was begun, during the early part of the seventeenth century, by the Dutch West India Company which brought sawmill machinery from Holland. The demands of the domestic market proved to be so limited that an outlet for the surplus was sought in Great Britain and Holland, and this export trade proved to be the chief impetus to the development of the industry in New York State.

Throughout the Northeast, rivers played an important part in influencing the direction in which the industry spread, because as the timber near settlements became depleted the mills had to seek more distant sources for their raw material, and the rivers, lakes, canals, and coastal waters were the only available means of long-distance transportation. In Maine the sawmills were placed on the lower reaches of the streams and the logs floated to them, while in New York State some of the earlier mills were placed in the vicinity of the forests and the sawed lumber rafted to the larger cities near the mouths of the streams, where the lumber was sold for local consumption or loaded on vessels for shipment to domestic and foreign markets. The industry in its gradual western migration followed two general routes, one across New York and Pennsylvania, following the rivers, and the other along the Great Lakes. It was not until settlements in the Ohio Valley began to take on the semblance of small cities that lumbering became of real importance in that region. It first spread into this section from the territory of the Allegheny and Monongahela rivers in Pennsylvania, following down the Ohio River, where the industry ultimately assumed large proportions in Ohio, Indiana, Kentucky, and Tennessee. At about the same time that it was moving southward, it also was extending westward along the Great Lakes, starting first in Michigan and later moving into Wisconsin and Minnesota. In this region the peak of production was reached about 1890.

Lumber production began on an extensive scale in the vast interior forests of the South only when it was evident that the peak of production in the Lake States was approaching its maximum. During the late seventies and early eighties of the last century many operators from Pennsylvania, the Lake States, and other eastern regions began to acquire holdings in the interior southern pine region and by the late eighties production of southern yellow pine was well under way. Only limited quantities of south-

ern yellow pine were marketed north of the Ohio River previous to the construction of the World's Fair buildings in Chicago in the early nineties. These were built chiefly of southern yellow pine because of its relative cheapness. The westward march from the Lake States also started at about the same time as that towards the South and lumbermen sought new supplies in the "Inland Empire" of Idaho and Montana and also in the Pacific Northwest, to which region many lumbermen from the South also have emigrated in recent years. Lumber manufacture was begun on a small scale on the North Pacific Coast as early as the late forties of the last century and in the Redwood region as early as 1851, but the industry remained of minor importance until the completion of the Northern Pacific transcontinental railroad in the early eighties and the Great Northern Railway in the nineties, which opened up new markets in the Middle West for the lumber products of Washington and Oregon.

The progress of the lumber industry from the early centers of settlement along the Atlantic Coast to the west and south was relatively slow for many years, but with the advent of improved forms of transport and rapidly increasing population it spread in an ever widening circle and at an ever increasing rate, and during the last 50 years there has been much more timber cut and utilized than during the entire previous period of settlement.

The Character of the Industry. The field of the lumber industry embraces the harvesting of the raw-wood materials found in the forests, their preparation or manufacture into some form of merchantable products, and the sale and distribution of the latter.

Logging is distinctly pioneer in character, because the work is done in more or less sparsely settled regions in which all forms of transportation often are lacking or poorly developed and is carried on under conditions which require the exercise of great ingenuity and resourcefulness combined with engineering skill. It includes felling the trees and cutting the boles into logs for lumber manufacture, or the conversion, in the forest, of timber into poles, posts, hewed cross-ties, hewed staves, rived shingles, and other materials which may be used with little or no additional preparation.

The process of converting logs into some form of sawed products, such as boards, dimension stock, and timbers is known as lumber manufacture. This work is done at a sawmill plant equipped to break down the logs into sawed materials, which are then seasoned

and later remanufactured into those products which the markets require.

The sale and distribution of the products of the industry comprise both wholesale and retail merchandising, each being a distinct and separate operation, the manufacturers being interested, chiefly, in wholesale distribution and often having no direct connection with the retail trade.

Another field in which many lumbermen are interested is that of forest-land ownership. Some individuals or firms own or control large areas of forest land from which their supply of raw material, in whole or in part, is secured. At the present time nearly one-half of the standing timber in this country is owned or controlled by approximately two hundred and fifty ownership groups.

The lumber industry comprises many producing units, most of them having a very limited annual output, and, because many small mills often cease to function during depressed market periods, the number of operations changes from time to time. The chief reason for this variation in numbers is that the lumber-producing capacity of the country is in excess of the consumption requirements, and since many small mills operate on a narrow margin of profit, they are among the first to be eliminated when the sale price of lumber declines to a point approximating cost. Up to the year 1850 a plant with an annual output of one half million board feet was considered a large one. Since this time mills with a larger output have become a greater factor in total production although their numbers still constitute only a small per cent of the total.

In general, the lumber producer has been too individualistic in his viewpoint to desire to lose his identity in a large corporation. The character of the industry also is such that it is not feasible to concentrate manufacture at a few points because the raw material is bulky and expensive to transport and must be converted in the vicinity of its origin. Therefore, the consolidation of manufacturing interests into a few large units or groups is less common than in some other forms of industry. The larger manufacturing units produce, annually, from 25 to 75 million board feet. There are only a very few organizations which have an annual capacity, from one group of mills, of 200 million board feet. There are some groups of manufacturers who control a number of large manufacturing units which usually are operated as separate corporations.

Some of the largest producing units have been built during the

last five years, chiefly in the Pacific Northwest. The justification for the establishment of additional large mills in the face of an existing surplus-producing capacity throughout the country, is that the ownership of extensive areas of forest land is proving a financial burden which can be mitigated only by cutting the timber and manufacturing it into a salable product. Lumber merchandising also is now so competitive that it is becoming more necessary to handle a large volume of lumber in order to distribute it economically. The largest consolidations within the industry are engaged in the distribution of the products manufactured by mills which have an interlocking directorate or which handle the output of mills, under agreement.

There is now under consideration a merger of Pacific Coast mills in the Douglas fir region which will have a total annual output of several billion board feet. This plan, if consummated, will tend to stabilize the merchandising of Douglas fir and other western lumber products and make possible a closer utilization of raw material and also should yield an adequate financial return on the capital investment which is not possible under present conditions. Such a merger should be most beneficial, both to the industry and to the public, because the inadequate financial returns to the industry in that region, during recent years, have had a tendency to hasten the depletion of the forests since only the better quality of raw material now can be marketed at a profit.

The larger lumber companies are incorporated, and their assets, comprising raw material and plant equipment, often are valued at several million dollars. Ownership is usually vested in a relatively few stockholders, and only rarely is any stock in such companies offered in the general market, however the stock of one company is now listed and traded in on the New York Stock Exchange.

The industry frequently secures a portion of its working capital by the issuance of " timber bonds, " for which the standing timber owned by the corporation is offered as security. These bonds, which carry an interest rate of from $5\frac{1}{2}$ to 7 per cent, have met with ready sale on the open market.

The reports of the Census Bureau are the chief source of data with reference to the number of firms engaged in the lumber business. The report for 1909 showed approximately 42,000, and that for 1919, 29,534 active mills, a decrease of 23 per cent, which was accompanied by a 27 per cent decrease in reported output.

The sawmills of the country classified by annual producing capacity, the per cent of the total number of mills in each class, and the per cent of the total production manufactured by each are shown in Table I.

TABLE I

PER CENT OF SAWMILLS IN EACH CLASS AND PER CENT OF TOTAL PRODUCTION MANUFACTURED BY EACH, 1924

Class	Annual Capacity board feet (000 omitted)	Per Cent of	
		Total Mills	Total Cut
I	50 to 499 M	55.61	4.34
II	500 to 999 M	17.88	4.94
III	1,000 to 4,999 M	17.24	13.15
IV	5,000 to 9,999 M	3.23	9.56
V	10,000 to 14,999 M	1.88	9.20
VI	15,000 to 24,999 M	1.81	14.00
VII	25,000 to 49,999 M	1.59	22.14
VIII	50,000 and over M	0.76	22.67
	Total	100.00	100.00

The above table shows that although the larger mills (Classes VI to VIII, inclusive) represent only above 4 per cent of the total number, they produce 59 per cent of the total volume, while the smallest mills (Classes I and II), which represent 74 per cent of the total number, produce less than 10 per cent of the volume. The annual cut, therefore, is determined chiefly by the number of large mills in operation. These do not vary greatly from year to year although in dull times their output may be curtailed.

More than 70 per cent of the largest mills (Class VIII) are located in the West, and approximately 22 per cent in the South, but due to the depletion of the supply of virgin southern yellow pine timber and the consequent closing of large Southern mills this ratio is gradually changing.

The West also has fewer small mills than other sections because the large-sized timber found in portions of that region requires expensive equipment to bring it to the manufacturing plant, and the small-mill type is not well adapted to convert large timber into lumber. Small-capacity mills are found in greatest numbers in regions which have been worked-over by the larger producers who have cut the more or less solid blocks of timber but who did not find

it practicable to utilize small, scattered virgin and second-growth timber holdings. The chief regions in which small mills are found are the Southern, Northeastern, and Central, in which lumbering, on a large scale, has ceased or is rapidly declining.

Small units usually own only a very limited amount of raw material which they acquire as needed for operation, while the owners of mills of Classes IV to VIII inclusive, especially Classes VI to VIII, often are large holders of raw material and are both loggers and manufacturers. In some parts of the country, however, where formerly logs were floated down large streams, logging and manufacture were conducted by separate firms. This also is now true to some extent in parts of the Far West, where mills are tributary to tide water or to large navigable streams.

Census returns tell us but little about lumber production up to the middle of the last century. However, we know that the annual output up to 1830 was relatively small. From 1830 to 1850 production increased rapidly and more than doubled during this period. The first reasonably accurate census returns were those of 1850, which indicated a lumber production, during that year, of 5 billion board feet or 215 board feet per capita. From this time on population increased rapidly, new agricultural territory was opened up in the Prairie Regions, industry developed, and likewise the demand for lumber.

The trends in production, by decades, are shown in Table II and the shifts in the centers of production from decade to decade in Table III.[1]

Up to 1870 the Northeastern States led in lumber production, being supplanted during the following decade by the Lake States, which were predominant during the next two decades, they in turn giving way to the Southern States, which since 1899, in given years, have produced from 32 to 47 per cent of the total lumber cut of the country. The rapid increase, during the last 15 years, of the output of the Western States indicates that the center of production is shifting rapidly from the South to that region.

The Relation to American Industry. The lumber industry has been closely allied with the development of other great industries in this country because there is scarcely an activity of man in

[1] See Bulletin No. 1119, United States Department of Agriculture, Washington, 1923, and Forest Products, 1924; Lumber, Lath and Shingles, Department of Commerce, Washington, 1925.

TABLE II

APPROXIMATE LUMBER PRODUCTION AND STATES LEADING IN PRODUCTION

YEAR	BOARD FEET (000,000 OMITTED)	CHIEF STATES
1850	5,000	New York, Pennyslvania, Maine
1860	8,000	Pennsylvania, New York, Michigan
1870	13,000	Michigan, Pennsylvania, New York
1880	18,000	Michigan, Pennsylvania, Wisconsin
1890	23,498	Michigan, Wisconsin, Pennsylvania
1899	35,078	Wisconsin, Michigan, Minnesota
1909	44,510	Washington, Louisiana, Mississippi
1919	34,552	Washington, Louisiana, Oregon
1925	38,339	Washington, Oregon, Louisiana

TABLE III

THE PER CENT OF TOTAL LUMBER PRODUCTION IN THE VARIOUS FOREST REGIONS OF THE UNITED STATES, 1850–1924

SECTION	1850	1870	1880	1890	1899	1909	1919	1924
Northeastern . . .	54.8	37.8	25.8	19.8	16.3	11.7	7.5	4.5
Central	18.6	20.0	18.4	13.1	16.1	12.3	8.7	5.7
Southern	13.6	9.4	13.8	20.3	31.7	44.9	46.6	45.2
Lake States . . .	6.3	24.4	34.7	34.6	24.9	12.3	7.8	6.5
Western	5.9	4.9	4.5	9.6	9.9	18.4	29.2	37.9
All Others	0.8	3.5	2.8	2.6	1.1	0.4	0.2	0.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

which, in some form or other, wood is not required either directly or indirectly. It can be said truthfully that our need for wood is secondary only to that of food. Although substitutes for many uses have been found there is little probability that any satisfactory wood substitute will be discovered for certain fundamental purposes. More than one half of our population dwell in wooden houses and use furniture and many household necessities built chiefly of wood, and there are few buildings of any kind in which wood is not employed either during the process of construction or in the structure itself. Every ton of coal that is mined requires wood and the latter enters into the mining of nearly every other metal. The production of oil calls for enormous quan-

tities of sawed lumber for derricks and pumping rigs. There is scarcely a tool or machine which is manufactured in which wood does not enter either in its manufacture or its shipment. Our land transportation systems are dependent on the products of the lumber industry. Railroad roadbeds are laid on hundreds of millions of cross-ties, and each year large quantities of them are needed for renewals in addition to the lumber used for car construction, buildings, bridges, and other structures necessary for operation. The products of the lumber industry also play an important part in motor transportation, for in automobile and truck manufacture about $\frac{1}{18}$ of the total lumber production is used, annually, for the manufacture of wheels, bodies, and crating. We consume a large volume of lumber in the manufacture of wooden packages, crates, and other containers.

Labor and the Industry. Logging and lumber manufacture provide employment for approximately one half million workers, almost exclusively male, and pay these men nearly 500 million dollars in wages. It is the largest single employer of workmen in eleven states,[1] in five of which[2] it furnishes a means of livelihood for more than 50 per cent of the population.

The demands for labor in the lumber industry were seasonal until logging railroads were introduced. Logging first was confined chiefly to the northern forests where snowfall was ample for sled hauling to streams, which were the chief means of transporting raw materials to the mills. Work began in the late fall and was continued until the logs had been floated down the streams the following spring. Sawmilling began as soon as the streams were free from ice, utilizing, first, a reserve supply of logs held over from the previous year, and later manufacturing lumber from the supply brought down during the early spring. Many woods workers sought employment in the mills during the early summer and remained until fall, when they again returned to the forest. Sawmilling ceased as soon as ice closed the streams. When the industry moved into other regions, such as the South and Far West, where snowfall was scanty or lacking and where the streams were not well adapted to log floating, lumbering lost its seasonal character. In the most important lumbering regions, labor now is required

[1] Washington, Louisiana, Mississippi, Oregon, Arkansas, Idaho, Florida, Virginia, Alabama, California, and Texas.

[2] Idaho, Mississippi, Arkansas, Washington, and Oregon.

throughout the year, and even in northern forests, the period of time, both for logging and milling, has been extended.

For many years, loggers, especially, were drawn chiefly from rural communities, the agricultural element finding in this occupation an opportunity for remunerative labor during the periods when their services were not required for the production of agricultural crops. These men were skilled in the use of the ax and saw and in handling work animals and, therefore, provided an excellent type of labor for the industry. The sawmills also drew their labor supply from similar sources, and the proverbial mechanical skill of the Yankee was renowned in every forest region.

The development of other forms of industry withdrew from lumbering a portion of the native labor, and recourse was necessary to foreign workmen, often with little or no previous lumbering experience.

In general, more than one half of the laborers in the industry are from foreign countries, north of Europe peoples being in the majority, although there are many from the south of Europe. The only sections of the country in which native-born laborers still predominate in the lumber industry are in the southern pine and cypress regions, where native whites and negroes are the chief workers.

There is a wide range in the skill required on the part of workers in the industry. There are but few kinds of labor in logging which can be performed by the wholly unskilled worker, although highly trained craftsmen are seldom required except for the care of machinery. The work is performed in the open in all kinds of weather and under constantly varying topographical and physical conditions, all of which call for resourcefulness and ingenuity. Sawmill labor works under conditions more nearly analogous to those in a factory where there is a more or less definite routine. But even here there are few kinds of work in which some degree of skill is not required. Craftsmen possessing a high degree of technical ability are required for operating and maintaining the equipment of the modern electrically-driven mills.

Wage scales in the lumber industry throughout the country vary greatly by regions and often there is a rather marked difference between plants in the same locality. This is less true, however, in the Pacific Northwest, where the unionization of labor has had a tendency to stabilize wage conditions. The United States Depart-

ment of Labor says:[1] "There is nothing even resembling standardization either of wage rates, hourly earnings, labor cost per 1000 board feet, either by occupations or as a whole, or of efficiency and productivity of labor as measured by board feet per one-man hour in any occupation, group of occupation, or all occupations in the lumber industry in the United States."

Although the lumber industry competes with other industries in the same region for wages, the annual wage returns per man usually are less than those received by workers in factories, manned by males, because the work is performed in unsettled or in small rural communities in which living costs are lower than in the larger cities in which factories usually are located. The forest and sawmill workers in the southern pineries do not receive as high a wage as those in the Pacific Northwest. This may be ascribed to the fact that, as a rule, the southern logger and sawmill worker does not possess a roving disposition and local ties are strong. He, therefore, is less attracted by higher wages elsewhere than the more restless and unattached labor frequently found in the industry in the North and West. Negro labor, which is employed in great numbers throughout the South, also has a tendency to depress the general wage level because negroes successfully compete with whites for all places, except those requiring the higher degrees of skill.

There has never been a national organization of labor in the industry, although various efforts have been made to organize forest and mill workers in given producing regions, especially in the Pacific Northwest.

Some of the early trade-union organizations in the field of the lumber industry were locals of the "Knights of Labor," which were organized in the South in 1899 and which were active in strikes in sawmills in the vicinity of Pensacola, Florida, during the latter part of that year. The chief demands made by the Union were shorter hours of labor and the abolition of doctor and hospital fees. Other sporadic efforts to organize labor in the southern lumber industry were made later, especially in 1911, when a Brotherhood of Timber Workers was organized in Texas and Louisiana, with the object of securing shorter hours, higher wages, and a recognition of the Union. None of these efforts proved successful and no further serious efforts at unionizing southern labor in the industry have been attempted.

[1] Monthly Labor Review, Vol. XVI, No. 1, Jan. 1923. U. S. Dept. of Labor, Bureau of Labor Statistics, p. 21.

The failure of these efforts was due to the absence of a large foreign element among the laborers and to the large proportion of negro laborers employed who did not appear to manifest much interest in such organizations.

Labor unions among forest and mill workers in the Pacific Northwest have been more successful than in other regions because a larger proportion of the workers are migratory and without home ties and, therefore, they are more susceptible to organization.

Union organizations first appeared in the Northwest in 1890 among shingle workers, who represented a relatively small group who were employed chiefly on piece work. The first organization, known as the West Coast Shingle Weavers' Union, was chartered by the American Federation of Labor and the locals were held together rather loosely by a "grand council." This organization sponsored, unsuccessfully, several strikes designed to improve the wage situation. Later the name of the above organization was changed to the International Union of Timber Workers and by amalgamation with sawmill workers and woodsmen greatly widened its scope. This consolidation lacked sufficient support to carry on the work successfully and, in 1915, the American Federation of Labor revoked the jurisdiction of the Union of Timber Workers over the sawmill and woods forces. The shingle weavers then reorganized under the name of the International Shingle Weavers' Union of America, the members of which have, in recent years, allied themselves chiefly with the dominant organization in that region, namely, the Loyal Legion of Loggers and Lumbermen.

The Industrial Workers of the World also played a prominent part in the labor field in the Northwest from 1905 to 1917. The membership of this organization was composed chiefly of migratory labor groups in whose minds revolutionary doctrines readily found fertile soil. Their activities were evidenced on various occasions by strikes and sabotage in mills and camps and culminated in 1917 in a series of the most serious strikes which have ever occurred in the ranks of lumber industry labor. These strikes were designed chiefly to secure the establishment of the 8-hour-day principle, which was strongly fought by the employers. By August, 1917, a large proportion of the workers in the industry were idle, although the number of actual strikers was probably only a small per cent of the total. Many of the operations had been forced to close down and production of timber for the military needs of the

United States and its allies was seriously curtailed. The backbone of the strike was later broken through the action of the War Department in sending troops into the region to protect mills cutting timber for military purposes and through a realization on the part of the I.W.W. that the lumber producers could not be brought to meet the Union terms by means of a strike. The organization, although not calling off the strike, permitted its members to return to work in order that the desired object might be secured by a "strike on the job," which would slow down production and thus curtail output. This action greatly embarrassed the employers and led to a continuance of unsatisfactory production conditions. The situation continued so unsatisfactory that, in November, a patriotic organization sponsored by the War Department, and known as the Loyal Legion of Loggers and Lumbermen, was organized which included in its membership both employers and employees.

The constitution of the "4 L's," as the organization was generally known, stated that "Its objects are to promote a closer relationship between the employer and the employee in the lumber industry in the Northwest; to standardize and coördinate working conditions; to improve the living environment in the camps and mills; to infuse a spirit of enthusiasm during the present national crisis; to stimulate the production of lumber for war purposes and stamp out sedition and sabotage in the Pacific Northwest."

The 4 L's was not organized as a labor union in the common acceptance of the term, but was purely a patriotic organization of both operators and operatives. It pledged itself not to interfere with or attempt to disrupt legitimate labor unions. As originally planned, the 4 L's was chiefly an agency for holding in check the I.W.W. movement, but later it was reorganized and took a more active part in labor administration. It then concerned itself with hours of labor, wage rates, living conditions, "open shop," and other matters essential to the contentment of the labor interests. As ultimately developed, the affairs of the organization were directed through a central organization with which district and local organizations of employees and employers were closely affiliated. Following the Armistice, the "4 L's" was reorganized as a private union, embodying, however, many of the ideas developed in the original organization. Although it has met with opposition from some of the earlier organized labor groups, it still is and probably

will continue to be the most vital factor in the labor situation in the Pacific Northwest.

Technical Improvements in the Industry. Logging. The first step in the process of manufacturing lumber is the felling of the timber in the forest and its transport to the manufacturing plant. In northern forests, where lumbering first began, this work was done during the fall and winter months by settlers who felled the trees and cut them into logs with an ax, and by means of oxen dragged them to some near-by point along a sled road over which they were hauled on sleds to a near-by sawmill or to a stream, down which they were floated to market during the following spring. On steep slopes on which sleds could not be handled the logger devised log chutes in which he dragged or slid the logs to the lower levels, where they could be hauled on sleds over snow or iced roads. Small operations were carried on by settlers who often lived at home, while the large ones required camps, often at a considerable distance from settlements, in which the workmen were housed. In the South, where snow was not available as a hauling bottom, carts and wagons were used for transporting the logs, and the operations were carried on for longer periods, sometimes throughout the entire year.

In the northeastern part of the United States, logging today is carried on in much the same manner as in Colonial times, although the use of the ax for felling timber and cutting the boles into logs long ago gave way to the cross-cut saw. The logger in other regions also employed simple equipment until the time came when the sawmills had manufactured a large part of the timber tributary to streams down which it could be floated. They were forced then to go into more remote regions, which led to the substitution of logging railroads for stream transport, thus making available to the industry vast areas of forest which previously had been inaccessible. This change in the form of transport began to develop in the early seventies, the period in which the lumber industry began to assume a truly national character, since rail transportation had made it possible to reach distant markets with carload shipments.

The introduction of logging railroads opened up new operating possibilities to those who had difficult physical obstacles to overcome or who had larger-sized timber than could be moved readily with animals. As early as the eighties loggers began to experiment with various forms of steam-driven, mechanical equipment

by means of which logs could be drawn to the roads by means of wire cables. Power methods, especially adapted to logging large-sized trees and also heavy stands of timber located in rough or swampy bottom, came into extensive use, both in the South and West during the early nineties. The present-day machines are powerful mechanical devices driven chiefly by steam power, although electrically-operated equipment has been installed on a few large operations and its use is gradually increasing.

The logger has been quick to adopt new methods and devices and he now employs nearly every conceivable form of transportation equipment known to man, including sleds, carts, wagons, railroads, chutes, flumes, aërial trams, tractors, and motor trucks.

Lumber Manufacture. — The first wooden houses in which the settlers in this country lived were made from logs fashioned solely with the ax, and such pieces of lumber as were required for the single door and the rude furniture were split from straight grained logs and the various pieces joined together with wooden pins. The pioneer soon began to seek a more efficient method of making such lumber as he needed and for this purpose he adopted a method called "whip-sawing," in which the boards were sawed by hand instead of being split from logs. This method proved too tedious for manufacturing lumber for commercial purposes, and power-driven saws, operated in connection with a water-power grist mill, were soon introduced. In the first type of power sawmill the lower end of the saw was attached to the pitman of a water wheel and a spring pole served to raise the saw on the up-stroke. These mills were devoid of other mechanical equipment and required the services of a laborer to feed the log against the saw.

Later the saw was stretched in a frame which was raised and lowered, between side guides, by means of a pitman. In order to increase the capacity they sometimes placed two or three saws in one frame. Modern machines similar in character may have as many as 60 blades stretched in a frame and spaced to cut lumber 1-inch in thickness from logs which have been slabbed on one or more sides. Mechanical devices for feeding the logs against the saw also were gradually perfected. About the middle of the last century sawmill men became interested in the circular saw for cutting lumber, and its first successful use dates from about 1860, although it was some years later before it was extensively adopted. It proved to have much greater capacity than any

other type of saw then in use and brought about a need for more efficient mechanical devices to handle logs and lumber, and as these were perfected the industry passed from a manual into a mechanical stage.

The circular saw had its limitations as to the size of logs that could be handled, because saws of a diameter greater than 72 inches were not practical mechanically; also the lumber was not sawed as true to thickness as it had been on the sash saws, and for each cut made, about $\frac{5}{16}$ of an inch of wood was converted into sawdust. Hence, as raw material increased in value some form of saw was desired which would not make as wide a cut as a circular, thereby making it possible to get more lumber from a given volume of logs. As early as 1855 experiments were made with a form of band saw or ribbon of steel which traveled, like a belt, around two wheels placed one above the other. One edge of the saw was toothed and the log, supported on a power-driven carriage, was forced against this cutting edge. The first band saws were not a success because steel which would withstand the constant bending around the wheels had not yet been perfected. It was not until 1889 that band saws reached a point of mechanical perfection which justified their extensive use. Today they have almost entirely supplanted the circular saw in nearly every large sawmill. The sash-gang is still extensively used in mills as auxiliary sawing equipment, cutting material that has been partially worked on a band head-saw.

The development of equipment for manufacturing lumber has kept pace with the growing needs of the industry, and much ingenuity has been displayed in devising machinery for special needs. For many years, the mechanical equipment of the modern sawmill in this country has been without a peer in any country in the world. Electricity as a form of power in sawmills was first introduced about twenty years ago and is now a common form of drive both in sawmill plants and in planing mills.

Coincident with the many improvements in manufacturing equipment there has been marked progress in the technique and precision of manufacture and in the extent to which remanufacture is carried on at the sawmill plant. For nearly 250 years the lumber producer was not concerned with the manufacture of his product beyond the rough stage. Boles cut into logs by means of the ax often had ragged ends, and since the manufacturer did not trim the boards, many of them had uneven ends. Lumber was made square-

edged by squaring the log before it was cut into lumber, hence there was a variation in width. It was not assorted into uniform widths and lengths, therefore a buyer might get numerous sizes in a given purchase. Much of the product was piled poorly for seasoning, and those boards which contained sapwood often became stained or moldy.

The manufacturer did not attempt to sell directly to the consumer, but disposed of the output of his mill to some wholesale dealer, located at a strategic distributing center, who at first handled only rough lumber which the carpenter remanufactured, by hand methods, into flooring and other forms of "finish." As early as the forties of the last century there were attempts made to substitute machine for hand dressing of lumber. A firm in Albany, New York, a great wholesale lumber distributing center at that time, set up a small plant in which a rotary-knife planing machine was installed. This plant was so successful that similar plants were soon installed in other cities and a large custom planing-mill trade was developed. Although these machines were a great improvement over hand methods, because of the reduction in the cost of dressing lumber, they were much inferior to the modern planing equipment which not only has a much greater output, but also does superior work, not only surfacing lumber but also working it into pattern stock.

The lumber manufacturer made but little effort to remanufacture rough lumber until the mills tributary to water transportation had exhausted the greater part of their available supply of raw materials and new ones had been established in the interior from which shipments were made by rail. This movement began in the seventies of the last century and was in full swing in the eighties. The chief impetus to the establishment of planing mills at sawmill plants was that it made possible the preparation of lumber in a form which was ready for immediate use by the carpenter and, therefore, the manufacturer could sell and ship in carload lots directly to the retail lumber dealer. Freight charges on rail shipments also were higher than by water transport because the rates for the former were based on weight and for the latter chiefly on volume. Surfacing lumber at the sawmill plant reduced the rough lumber to the finished form required for ultimate use, and the material removed from the board in dressing, often weighing from 800 to 1000 pounds per thousand board feet, reduced the rail freight charge to a mini-

mum. Today the custom planing mill is of much less importance than formerly, because every sawmill, even of average capacity, has some lumber-dressing equipment.

When the lumber producer began to ship by rail and to dress lumber, he found it necessary to season his product more carefully. Buyers of dressed stock did not desire pattern lumber that had become stained or moldy in seasoning; also lumber that was to be worked into pattern stock or flooring had to be dry because, during the process of seasoning, green stock does not always shrink the same in width and thickness. An additional reason for more thorough seasoning was that green lumber contains water which adds appreciably to the weight of the lumber and buyers object to paying freight on moisture which later evaporates as the boards season. Artificial seasoning in heated chambers, called dry kilns, was introduced to hasten the drying process and make lumber available for use within a few days instead of within two or more months, which latter period often was required when lumber was piled and seasoned in the open. Nearly all large softwood sawmills now season at least a portion of their product, usually the best quality of lumber, by artificial methods, and a few mills season their entire output in this manner.

Hardwood lumber is handled in a different manner from softwoods because the rough product is sold chiefly to wood-using industries which cut it into smaller pieces and manufacture a great variety of products from it. The sawmill man often does not dress or work hardwood lumber to patterns, and only partially seasons the rough product, which is later thoroughly dried at the factory.

The machine work on lumber now produced in a sawmill is far superior to that of 25 or 30 years ago. Stock which is not properly sawed, carefully seasoned, well manufactured, and delivered into the hands of the consumer in first-class condition, can no longer be sold advantageously.

Lumber Merchandising. The sales problems of the lumberman of 50 years ago were far more simple than they are today because the chief demands for lumber were for local building purposes which required only a few qualities of high-grade lumber. The buyer often went directly to the sawmill, where he selected the material desired which was delivered on the construction site in the vicinity. When the supply of raw materials near the settlements became depleted and the mills were forced to move to more remote points,

the builder could no longer deal with the producer directly and retail lumber yards were established. Wholesalers or middlemen then appeared in centers which were tributary to the sawmills by water, and established distributing yards from which local sales were made to retail yards and shipments also were consigned to other near-by markets which could be reached by canal boat or sailing vessel. The retail dealer often bought his annual needs at one time and, if he was not on a waterway, he sometimes rented storage space until he could move his product advantageously. The lumber producer sold his rough product on a "mill-run" basis, that is, the middleman bought an unassorted lot of lumber. The producer had no direct business relations with the consumer and knew but little about him and his needs. In most of the distributing centers the middleman formulated, gradually, a simple method of lumber assortment, and trade customs based on local conditions came into use. The producer took but little part in this work because he was concerned only with the disposition of his output en masse. He continued to dispose of his lumber through the wholesale dealer until the supplies tributary to the distributing markets, on a water haul, had been depleted and many mills had moved to other regions in the interior, from which points lumber could be shipped only by rail.

The decline in the importance of the distributing centers as a market for the producer was gradual even after the movement of the mills to the interior because there had developed in the market centers custom planing mills which were designed to dress lumber for the building trade, and the sawmill man, unfamiliar with this remanufacturing process, only gradually undertook this new form of work. However, manufacturers early realized the desirability of eliminating the distributing centers and making direct contacts with the retail lumber yards which were increasing rapidly in rural centers distant from the wholesale markets. The larger producers, therefore, began to enter the wholesale field in competition with middlemen who, realizing the changes in marketing conditions which were taking place, began to build up a jobbing business by purchasing lumber from interior mills and shipping it directly from the mill to the retail yards and to the large industrial buyers.

Many new problems confronted the manufacturer when he became a wholesaler because he had not previously developed sales technique, and he lacked adequate rules for grading and classifying

his product in a uniform manner which would meet the diversified needs of the buyers to whom he had to cater. He did not have a uniform basis of credits and collections and codes of ethics to guide him in his relations with other producers, and with the wholesale and retail trade, and also he was more or less unacquainted with the requirements of the various industries which represented the ultimate consumers of his product.

The agencies engaged in domestic wholesale distribution today are the manufacturer, the wholesale dealer, and the commission agent. The manufacturer often maintains a sales department which disposes of the products of his plant directly, although he may utilize the services of the wholesale dealer or commission man when he desires to sell special stock or to move quickly certain products. Firms having common business interests sometimes form sales agencies through which the output of the member mills is placed on the market, thus reducing the cost per unit of sales, and providing a greater volume and variety of products which facilitate sales to the larger industrial buyers. Such organizations also have found it feasible to study more closely the needs of special industries and the development of markets, which makes possible a closer utilization of the raw material. These sales agencies also may be engaged either directly or indirectly in the retail lumber trade through the ownership or control of retail lumber yards.

The wholesale dealer, who may or may not be interested in production, is the chief salesman for mills of limited capacity, whose output does not justify the maintenance of an independent sales organization. He likewise handles a relatively large per cent of the hardwood cut of the country, which is purchased chiefly by industries whose needs frequently call for special qualities in lumber that do not coincide closely with the standard manufacturers' grade classifications. Many wholesale firms also have developed a specialized trade in construction timbers which usually must be accumulated from several mills, since a given plant seldom possesses the facilities or timber to supply more than a portion of a large order.

Although lumber is still sold on a commission basis the commission salesman now is a less important factor in lumber merchandising than formerly because producers often have found it unsatisfactory to have their stock marketed by one whose chief interest in a sale is the fee received.

One of the most significant changes in lumber distribution since the World War has been the greater rapidity with which lumber deliveries have been made by the railroads. The time of delivery has been reduced from one half to one third of the period formerly required, due to more efficient railroad service, and this has reduced the amount of lumber, by several billion feet, which formerly was in transit. The policy of retail yard buyers also has changed and instead of making heavy purchases in the summer and late winter for the spring and fall trade they now buy, in smaller quantities, more or less steadily throughout the year.

The lumber trade associations have been an important factor in the development of modern sales methods because, through the coöperative means provided by them, the lumber producers have been able to accomplish by united effort that which was not possible through individual action. They date chiefly from the early nineties of the last century, when producers were attempting to widen their markets and to take over, on a large scale, the wholesale distribution of their product. They have been organized in every large producing section and have played a prominent part in the development of better manufacturing and merchandising methods.

The finished products of the lumber industry vary far more widely in quality than those manufactured by many other industries, and lumber manufacturers' associations have devoted much time to the development of grading rules and to standardizing lumber products.

When lumber was distributed chiefly through wholesale centers, there was not much overlapping in territory in the sale of products. During the course of time each section developed rules, based on local needs, for grading the product of that particular market, and these rules while having some points in common often employed a different nomenclature and sometimes provided for different standards of size. This was of little importance so long as the products from one marketing district did not pass into the territory of some other district. When lumber began to move by rail from mill to market, products from a given mill were much more widely distributed and various kinds of lumber, used for similar purposes, but assorted in a different manner, came into competition, causing confusion in the minds of the buyers. Not only did the various market standards differ but even in a given producing region, which

extended over a large area geographically, several different standards often were developed locally. This variation in standards could be corrected only by coöperative effort on the part of many producers and the association was the logical agency to bring about the result desired.

Following the World War, during which there was more or less official standardization of many kinds of products, a movement was started to establish uniform national lumber standards which would enable a buyer to secure lumber for a given use from any and all regions on a uniform basis of grading and classification. The desirability of having such a standard had long been appreciated, but since manufacturers in every region were competitors not only of neighbor producers but also of those in other sections, it was difficult to secure concerted action. However, governmental agencies and lumber trade associations started a coöperative movement in 1922 looking toward this end, and since that time much has been done to clarify the situation in so far as softwood lumber is concerned. We now have uniform standard sizes throughout the country for softwood lumber which marks one of the most important steps ever undertaken for the better and more economical marketing of the sawed products of our forests.

The standardization of hardwood grading practice has not been completed, but marked progress has been made and some satisfactory solution of the problem is foreseen in the near future.

An important development in recent years in connection with the standardization of the products of the industry has been the progress made in grade-marking lumber and in the adoption of trade marks by individual firms and by associations. Some lumber trade associations have adopted the practice of having its membership stamp the quality on each piece of lumber in order that the buyer should have as certain a guarantee of quality and quantity in lumber as in any other form of merchandise he purchases. Certain associations and some firms also have recently adopted the practice of trademarking their products in order that they may capitalize quality and high-grade service and also show the producer's faith in his own products.

For many years the distributor of lumber has been confronted with increasing competition not only from woods other than those he handles but also from wood substitutes. Brick, cement, and steel have displaced a certain amount of wood used in building

construction. Steel now is employed extensively for office furniture, freight and passenger cars, wheel spokes, ships, and agricultural implements, and fiber containers are rapidly replacing wooden packages. There is scarcely a use for wood for which some substitute has not been provided. Substitution, to some extent, is inevitable, due to the diminishing supply of lumber, which has been used for many industrial and domestic purposes because it has been the cheapest material, although not necessarily the best, for the purpose. The industry recognizes that for some requirements the substitutes may be superior to lumber; on the other hand, lumber has so far proved more satisfactory for certain needs than any substitute that has been devised. The householder certainly prefers wooden to metal furniture, wooden flooring and trim to any substitute, and the wooden framed house still remains the standard style of structure for the small home owner because it is easily fashioned and repaired and when properly constructed embodies the qualities of warmth and pleasing appearance which are important factors to the owner and, when properly protected, it presents no greater fire hazard than its substitutes. Wooden cross-ties also are vastly superior to metal or concrete ones.

The lumber industry for a long time was ill prepared to combat the modern advertising methods of substitute manufacturers because it was organized chiefly into regional associations all of which represented less than one half of the total lumber production. These associations also were composed of members with widely divergent manufacturing and sales problems, and there was not that close harmony of effort displayed which was necessary to carry on an effective publicity campaign. Also each region had been devoting its efforts to increasing the sales of its own products in competition with similar products produced in other regions, whereas the interests of the lumber industry demanded national coöperation in furthering the use of wood as such rather than that of any particular species. The result of the aggressive advertising campaign of wood-substitute manufacturers, plus the seeming indifference of the lumber industry, led to the creation of an impression in the minds of the buying public that wood for building and industrial purposes was rapidly going out of fashion and, as a consequence, there was in evidence a reduced demand for lumber. A marked change in attitude on the part of the industry has been evident in recent years and its members, both individually and collectively, are

devoting large sums of money to restore lumber to its former place as a building and industrial material.

Domestic Trade. The domestic demand for lumber during the early days was chiefly for home-building purposes although at seaports there was a limited market for ship-building timbers and export stock. The per capita consumption of lumber was relatively low for more than 200 years because the various industries which now use large quantities of lumber had not yet been developed.

This country has been most prodigal in the use of its raw wood materials. Twenty years ago the per capita consumption was 500 board feet annually, but, due to lessened production and increased population, it has now declined to approximately 305 board feet. The United States annually consumes nearly 56 per cent of all of the sawed timber produced throughout the world, and its per capita consumption is more than twice that of England, France, or Germany. The centers of maximum lumber consumption in the United States are shown in Table IV.

TABLE IV

LUMBER CONSUMING REGIONS IN THE UNITED STATES

Region	Per Cent of Total Consumption
Northeastern States	25.0
Central States	22.0
Southern Pine Region	17.6
Pacific States	19.9
Lake States	10.5
All Others	5.0
	100.0

California, due to the extensive real estate development in its southern part, ranks first among individual states, followed, in the order of importance, by New York, Illinois, Pennsylvania, Michigan, Ohio, Texas, Washington, Massachusetts, and Indiana. The centers of maximum per capita consumption are not coincident with those of maximum total consumption because in those places where the total consumption is greatest, the population also is most dense. In general it may be said that the northern states consume more lumber per capita than southern states because industry is more

highly developed and the individual is better housed. Thus the average per capita consumption of the Lake States was 385 board feet in 1924, while that for South Carolina was 90 board feet, Georgia 120 board feet, and Oklahoma 165 board feet. Florida, using 540 board feet, was an exception, due to its real estate boom. Per capita consumption in each region usually is greatest in those states in which production is greatest. For example, the maximum consumption per capita, during 1924, was in Washington and Oregon in the West, and in Louisiana in the South. This was due to the relatively small population and the extensive use of wood. Throughout the United States there is a greater difference in consumption between states than exists between countries in Europe. As our virgin forest resources become more depleted and the less populous states become more densely settled, we may look for a more equable per capita consumption between states because agriculture and industry in many Southern States, where consumption is now relatively small, will require more lumber, and in the chief forested states in the northern part of the country there will be a less prodigal use of lumber because of the higher price which it will command. When virgin supplies have been depleted to a point where timber must be grown as a crop, forestry will be practiced on idle lands near the main centers of consumption in order to eliminate a long haul to market and reduce, to a minimum, that part of the lumber cost which is represented by transportation.

Approximately 82 per cent of the lumber manufactured in the United States is produced from coniferous trees, known as "softwoods," and is used chiefly for building construction and box and crate manufacture. Two kinds, namely southern yellow pine and Douglas fir, comprise 35 and 21 per cent, respectively, or 56 per cent of the total.

Hardwoods furnish only 5.9 per cent of the lumber required in building construction of all classes, and 2.8 per cent of that consumed in the box and crate industry, but they provide the greater part of the wood materials for all other industries. The small volume of hardwoods used in building construction is due to the fact that, in general, softwoods are more easily worked and nailed and are lighter in weight. Such hardwoods as are employed for building are chiefly for flooring and for interior work where "figure" is desired for natural finish. In industry, however, hardwoods find an extensive use because of their greater hardness, figure,

resiliency, absence of resin, or other special qualities which make them particularly adapted for special purposes, such as furniture, musical instruments, automobile bodies, woodenware, and similar products.

The data in Table IV show that the two largest centers of consumption are east of the Mississippi, in which districts the production of lumber is lowest. This deficit is due to the fact that the forest resources in these two regions, which were those in which lumbering was first developed, have been greatly depleted and they must depend upon other regions for the major part of their supply. These sections, for many years, have consumed more lumber than they have produced. They gradually extended the territory in which they purchased, first to the Lake States, and later to the South. When the supplies in these sections showed signs of depletion, buyers on the North Atlantic Coast began to import lumber from the Pacific Northwest via the Panama Canal, the shipments from the Pacific Coast in 1926 totaling nearly two billion board feet, which was 19 per cent more than the entire production of the ten Northeastern States and approximately equal to that of the seven Central States. This large volume of western lumber is sold in competition with lumber produced from local forests and, due to the low price at which it has been offered, has had a depressing tendency on local timber values.

An important change in distribution has taken place in recent years, namely, that no one territory may now be termed the sole and exclusive marketing region for any one producing section or species. Transportation has been perfected, so that more than one half of the total lumber consumption is in regions which may draw their supply from any one or all of the chief producing sections. Formerly, the trade in the Northeast was supplied exclusively from production in that region, and for many years, the Lake States dominated the Prairie markets. Today, the Northeast uses lumber from the Pacific Coast, the Gulf, South and North Atlantic States, the Appalachian region, as well as some from foreign countries. The Prairie States likewise draw their supplies from the South, the Pacific Coast, the Inland Empire, and the Lake States.

The market for Douglas fir on the Atlantic Coast increased more than thirty-four fold from 1920 to 1926. Among the reasons why Pacific Coast lumber can be sold in the eastern territory in competi-

tion with the local output are the relatively low water freight rates via the Panama Canal, and the recent installation of extensive distributing centers at Atlantic Coast points, as well as the fact that the timber of the Pacific Northwest is of such character that it produces a higher percentage of the better grades of lumber than the smaller timber of the East. Over-production and the excessive competition of western producers among themselves, lead to sales at a price which gives a low margin of profit; hence, in western woods, for a given sum, it is possible for eastern buyers to secure a better assortment of sizes and a higher quality of product than can be secured in local lumber. The result has been that Douglas fir has become the chief general construction wood at those points on the North Atlantic Coast which are within a short rail haul of tidewater.

Exports. Forest products originating in the United States have been a staple product in foreign markets for many years, because no other country in the Northern Hemisphere has possessed such a wide variety of woods of such high quality and abundance and adapted to so many different uses as has our own. The United States has species that are not found in commercial quantities, if at all, elsewhere, and even from similar species that are found in Europe, there cannot be produced the volume and high quality which can be secured from timber grown in our virgin forests because, except in restricted areas in Europe, the choicest timber has long ago been cut. Our extensive forests of Douglas fir, the counterpart of which does not exist elsewhere, furnishes trees from which the largest softwood timbers desired can be produced.

The export trade in forest products was developed only to a limited extent during Colonial days because the mother country did not encourage foreign trade with countries other than itself. The chief development followed the successful conclusion of the War of Independence.

From the standpoint of volume, the chief forest products exported have always been sawed materials such as boards, planks, and deals. Hewed and sawed timbers, masts, cooperage, and shingles also have been of some importance.

The early statistical records of forest product exports were neither comprehensive nor accurate, and during the course of years the methods of classifying forest products for census purposes

has undergone various revisions, so that a satisfactory comparable series of export data from the beginning does not exist.

The following table shows the volume by decades for those products which have represented the most important forms of forest products exported.

TABLE V

Exports of Board, Planks, Deals, and Scantlings

Year	Board Feet (000 omitted)
1790	46,717
1800	68,825
1810	63,042
1820	89,420
1830	67,300
1840	83,075
1850	74,743
1860	170,922
1870	140,863
1880	285,194
1890	612,814
1900	1,087,801
1910	1,710,761
1913	2,592,453
1920	1,551,612
1925	1,948,038

A rapid increase in the volume of lumber exports began first to appear in 1880, although there was evidence of the beginning of a rapid rise as early as 1860. From 1880 on, with minor exceptions, the upward trend was sharp, culminating in the maximum volume of exports of boards, planks, and scantlings in 1913. The increase in volume during this period was more than 900 per cent. The outbreak of the European War, however, caused a marked decline in exports, the low point being reached in 1917, during which year the exports were approximately 40 per cent below the 1913 peak. Since 1917, exports have again increased, the 1925 volume being 75 per cent of the maximum in 1913. It appears doubtful if the export of boards, planks, and scantlings will again reach the maximum, although the trend may continue upward for a few more years, because domestic demands will tend to absorb a larger per cent of the surplus than it has in the past.

The European trade in logs, timbers, and lumber has been chiefly with the United Kingdom and Germany, although Holland, Belgium, France, and Italy also have bought limited quantities of such material from us. White pine was one of the woods first exported in quantity to Europe. For many years the principal trade in softwoods has been in southern yellow pine, although Douglas fir has been gaining ground rapidly during the last ten years. Among hardwoods, oak, walnut, hickory, yellow poplar, gum, and ash have been of importance.

On the North American continent, Canada was formerly a relatively large purchaser of sawed lumber but, during the last decade, sales to this country have declined, due to the development of her own lumber industry. Mexico has a large forest area but it lacks adequate transportation to enable the cheap delivery of lumber to its own markets and it has depended primarily on purchases of southern yellow pine in the United States to meet its needs.

The West Indies for many years have purchased their lumber requirements in the Gulf Coast region from which southern yellow pine is shipped to them in sailing vessels.

The most extensive South American market for United States lumber has been Argentina. The forest areas in this country are relatively inaccessible, and this has made possible the development of an extensive market for southern yellow pine. Other countries on the East Coast of South America, due to their slow industrial development, use but little lumber, per capita, and they have depended chiefly on local supplies secured, in large part, from Brazil. The relatively small demands for lumber on the West Coast of South America are supplied mainly by shipments from the North Pacific Coast of the United States.

In recent years, Japan has been an extensive purchaser of timbers and lumber from the Pacific Northwest, and this country is the chief Asiatic market for United States woods. The lumber purchases of China, the only other important Asiatic market, vary from year to year; however, the average volume of trade is much less than that with Japan.

Australia has provided a limited market for West Coast woods but her total requirements are not great and, in part, are met by shipments for the forest regions of North Europe.

The African market is of minor importance, buying annually a

few cargoes of southern yellow pine and Douglas fir timbers and lumber.

Our export trade in lumber developed without organization, each firm operating more or less independently; as a consequence, foreign market conditions for our lumber often have been unsatisfactory, due to ill-advised shipments to markets already glutted or because of dissatisfaction with the quality of goods forwarded.

The American exporter was at a great disadvantage, especially in European markets, because he was in competition with long-established sales agencies in European competing countries which were well organized, and understood, in detail, the market requirements as to size and quality, and were familiar with the prevailing terms of credit and methods of doing business. The United States shippers until recently were forbidden, by law, to form organizations for marketing lumber abroad. However, the passage in 1918 of the Webb-Pomerene Act made it possible for firms or associations to coöperate for the purpose of promoting export trade, and several such companies have been formed to the mutual advantage both of the exporter of this country and the foreign buyer.

Imports. Although the United States has long been the largest lumber-producing country in the world, it is also a large importer of timber and lumber. The imports may be grouped under two main heads, namely, cabinet woods and general building lumber, the other wood imports comprising shingles, logs and pulp wood. Among the cabinet woods, mahogany is the most important, although many other kinds of tropical woods also are now offered in the market. The cabinet woods are used chiefly as substitutes for native species, competing with native oak, gum, walnut and cherry in the manufacture of furniture, interior trim, and for other purposes where special color or other qualities are desired which indigenous woods do not possess. Building lumber, which represents the greater part of the volume of lumber imports, comes from Canada. It comprises white pine, Douglas fir, spruce and hemlock of the common grades and is sold in this country in competition with similar lumber produced here.

The chief reasons why the United States is a large importer of building woods is that the local supplies in this country adjacent to the Eastern Canadian border have been greatly depleted, and Canadian shippers, especially those tributary to the Great Lakes, find it possible to sell their average quality of softwoods in direct

competition with southern yellow pine and Douglas fir, which can only be delivered within the Northeastern territory on a longer haul than the Canadian products. A large volume of the former white pine cut of the Georgian Bay district in Canada was marketed in the middle western part of the United States and much eastern spruce from the Maritime Provinces has been moved to North Atlantic markets in sailing vessels. The United States has always been the largest buyer of Canadian lumber and, because of the favorable location of Canadian supplies to United States consuming territory, this country will probably continue to absorb a large per cent of Canadian lumber exports.

The following table shows the imports of boards and other sawed lumber by decades, beginning in 1871.

TABLE VI

Imports of Boards, Planks, Deals, and other Sawed Lumber

Year	Board Feet (000 omitted)
1871	725,994
1880	515,343
1890	660,327
1900	680,226
1910	1,053,616
1920	1,338,530
1923	1,959,334
1925	1,815,066

During the year of maximum imports, 1923, nearly 2 billion board feet of lumber were imported, while the exports of similar material during the same year amounted to approximately $1\frac{3}{4}$ billion board feet. Softwoods comprised $95\frac{1}{2}$ per cent of the total lumber imports for 1925, and 99 per cent of this volume came from Canada. The chief sources of our mahogany imports are Central America and Africa, while the remainder of the hardwoods come chiefly from the Philippines and other tropical countries.

Although at various times there has been an import duty on lumber entering the United States, there also have been numerous periods during which rough lumber has been admitted free. Until 1870, the lumber industry of this country gave little attention to a protective tariff on products competing with their manufactures.

About this time, however, United States lumber producers began to meet with sharp competition from the lower grades of lumber from Canada and an agitation was started to build up a tariff wall which would reduce the competition from Canadian products.

Previous to 1872, the tariff imports usually were applied on an *ad valorem* basis, but, in the Tariff Act of that year, a specific schedule for forest products appeared for the first time, and import duties on lumber were assessed on the basis of the thousand board feet. A base rate was fixed for rough sawed products, increased charges being added for different degrees of manufacture. The base rate on rough hemlock, whitewood, sycamore, and basswood lumber, which was imported only in limited quantities, was fixed at $1 per thousand board feet, while for all other species, the duty on rough lumber was $2 per thousand board feet. The latter rate was applied to white pine and eastern spruce, which were the Canadian woods chiefly sold in this country.

This discriminatory import duty on lumber was distasteful to Canadian producers and Canada passed retaliatory legislation in the form of an export duty on logs, large quantities of which were then being brought into this country, free of duty, for manufacture at points on the Great Lakes. This export duty on logs proved a handicap to lumber manufacturers in this country who were using Canadian logs, and there soon arose a demand on their part for more satisfactory tariff relations between the two countries. This was adjusted by the McKinley Tariff Act of 1890, which provided that the import duty on rough lumber from those countries which did not impose an export duty on logs of pine, spruce, elm or other species should be $1 per thousand board feet. The Canadian Government then removed the export duty on logs which greatly stimulated the trade in the latter for a brief period. Four years later the Wilson Tariff Act placed lumber on the free list. However, lumber producers, except in the regions adjacent to Canadian supplies, were not in favor of "free lumber," and when, in 1897, a new Tariff Act was passed by the Republican majority in Congress, the $2 duty on rough lumber was restored. This action led to the placement of an embargo on the export of logs from Crown lands in Ontario, which action was later taken by various other forested provinces and by the Dominion Government. In recent years, this has forced pulp and paper manufacturers, especially those who utilize Canadian wood supplies from public lands, to move their plants

across the border. Since October, 1913, rough lumber has been admitted to this country free of duty but this has not led the Canadian Government to relax its log embargo.

In general, it is true that, except for brief periods, the importation of lumber into this country has not been seriously affected by the presence or absence of an import duty. The growth in imports since the early " seventies " has been relatively rapid both during periods when a duty was imposed and also when lumber was on the free list. This is due to the fact that, except for restricted regions, lumber producers have not suffered undue competition from such imports.

An import duty on lumber produces only a relatively small revenue, and since our needs for lumber are great, it is probable that, in future Tariff Acts, lumber will remain on the free list.

Wood, which is so essential to our personal comfort and national prosperity, unlike metals, is a renewable resource but an adequate future supply may only be assured by the adoption of more intelligent and far-reaching measures than are now in force. The present annual growth in our forests is only one fourth of the volume annually removed by lumbering or destroyed by fire and other natural agencies, hence drastic measures are needed to prevent the ultimate exhaustion of the supply. It is hoped that this brief survey may lead to added interest, on the part of the reader, in the forest problems of the country and in the industry which converts timber into products available for our use.

CHAPTER XV

THE PAINT INDUSTRY

By R. L. Hallett[1]

The American Society for Testing Materials defines paint as:

Paint — A mixture of pigment with vehicle, intended to be spread in thin coats for decoration or protection, or both.

The paint industry, therefore, is the industry which manufactures paint and uses it for the protection and decoration of buildings and other structures and objects of various kinds.

The paint industry, with which may be considered the closely allied varnish industry, is one of the most important in the United States and the products manufactured annually by this industry have a value of about $500,000,000. In 1919, the industry had capital invested in excess of $239,000,000, but since that time no statistics of invested capital have been issued. The invested capital and value of manufactured products give some idea of the importance of the industry, but these figures are insignificant when compared with the many billions of dollars invested in property in the United States which is protected and beautified with paint products.

The paint industry is highly technical in some of its phases and is closely allied with many other industries and activities of civilized peoples. It draws many of its raw materials from the basic industries of mining and agriculture, requires the use of advanced chemical and mechanical engineering in the operation of its manufacturing processes, and its success requires the application of sound business methods and a complete knowledge and understanding of industrial developments and the trend of financial conditions and world competition.

[1] In the preparation of this chapter the author was assisted and advised by G. W. Thompson, chief chemist, National Lead Company. The Author also is connected with the National Lead Company.

Paint in Ancient Times. No doubt mankind used paint for decorative purposes long before it was employed for protection, but the protective value of paint was well known to many peoples of ancient times.

The use of paint dates back almost to the beginning of civilization, but history contains few records of the industrial activities of prehistoric times because the art of writing did not develop until civilization had progressed to a somewhat advanced state and the art of printing followed at an even later date. Until writing and printing were extensively used, permanent records were not possible, and industrial information was not preserved in any form which would permit its study at a later time.

For this reason, we have very little knowledge regarding the use of paint in ancient times, but some information has been obtained by examining the remains of ancient structures and we have some early writings which are of great value although, unfortunately, very limited.

The art of painting was known and used by the Egyptians as early as the sixth dynasty, which was about 2500 B.C., and the Hebrews were familiar with the art before the time of Moses. The Hindus used paint as early as 200 B.C. and the Etruscans had a knowledge of paint which was probably equal to that possessed by the Romans at a much later date.

The best information concerning the use of paint in ancient times has been given to the world by the Greeks and Romans, largely because the art of writing, and the development of authors of ability, had progressed to such an extent under the Greek and Roman empires that records of some degree of accuracy and permanence could be prepared. These records, together with the examination of the remains of many buildings and other structures erected by the Greeks and Romans, which are still in a fair state of preservation, have furnished sources of information which can be studied at the present time.

Many materials are used in making paint, and perhaps the most satisfactory way to trace the growth of the paint industry is to follow consecutively the introduction and use of the various materials which have been of importance in its development.

Probably the first pigments used in decorative coatings were the natural mineral and earth colors, but white lead, the oldest and most important white pigment, and for many centuries the only

available white pigment, is most consistently mentioned in the early writings as well as in the later records, and the early history of the paint industry is best indicated by the growth in the use of this pigment.

White Lead Prior to the Nineteenth Century. White lead was used by the Egyptians, Greeks, and Romans, and was known to the ancients under the Greek name "psimithium" and the Roman name "cerussa." Pliny mentioned the use of natural lead carbonate (natural white lead) and also described the manufacture of artificial white lead with metallic lead and vinegar. A similar process was also described by Theophrastus in 300 B.C.

White lead was undoubtedly made in large quantities at the beginning of the Christian era, and Rhodes seems to have been the most important city in the white lead industry at that time.

All of the ancient records which refer to the making of white lead describe the use of metallic lead and vinegar, and it is interesting to note that this process was in use through all the stages of development in the manufacture of white lead and that the fundamental essentials of this process are being used in our modern factories today.

During the early part of the Christian era following the fall of the Roman Empire, culture and education did not develop with any rapidity and it was not until after the tenth century that any material educational or industrial progress was made.

The Crusades, which brought together people from many nations and required their travel in far distant lands, resulted in the widest mingling of different nationalities since the fall of the Roman Empire. The result of this mingling of different nations was a marked revival of commerce beginning in the ninth or tenth century, and industrial and manufacturing progress was stimulated by the eagerness of many nations to establish international commercial relations. The Italian cities were particularly progressive in pushing their maritime trade, and white lead and other paint materials received their share of growth in this great commercial development.

A number of medieval manuscripts contain references to the manufacture of white lead between the thirteenth and sixteenth centuries and some of these records refer to the use of earthenware pots buried in beds as well as to the use of lead and vinegar.

There is some difference of opinion as to where the Dutch process

for the manufacture of white lead originated and it is often stated that this process was developed in Holland, but some of the writings of the ancient Greeks apparently describe the fundamentals of the process which was taken up by the Dutch in the seventeenth century and developed by them until it became of great importance.

The manufacture of white lead probably was established in Holland in the sixteenth century and for many years there was considerable rivalry between the Dutch and Venetians in their endeavor to sell white lead in the markets of Europe.

Following the Norman conquest, England rapidly developed into an industrial and commercial nation and the white lead manufacturing industry was started in England and flourished from the beginning. All industries in England received great encouragement during the reign of Queen Elizabeth, largely due to the regulations prohibiting the importation of many products into England, and white lead was one of the products included in these regulations. This action is of great historical interest as perhaps representing the first, or one of the first, attempts on the part of a great nation to establish some form of protection for her own industries, and is possibly the foundation of later protection measures which grew into modern protective tariff systems.

After the manufacture of white lead became established in England, the rivalry for the trade of Europe continued between England, Holland, and Venice. At a slightly later date, the manufacture of white lead was introduced into Germany and at a still later date into France, Belgium, and the United States.

Prior to the nineteenth century, the development of the paint industry is best indicated by the growth in the use of white lead, although linseed oil, which probably was first used in paint about the sixth century, and some other paint materials had become of considerable importance in paint manufacture before the end of the eighteenth century. Even at that time, linseed oil was the most important paint vehicle, a position which it has continuously maintained in the paint industry and which it still occupies today.

A very large proportion of all paint used is either white or in light shades requiring a white base. For this reason the white pigments are the most important and the introduction and growth of the various white pigments to a certain extent indicate the development of the industry.

Advent of the Other White Pigments. The use of white lead continued to increase with the growth of civilization and the expansion of the paint industry, but beginning with the nineteenth century a number of other white pigments were discovered or improved and became very important.

As the newer white pigments were developed and were produced in quantities of commercial importance, they found their place in the industry. The introduction of the newer pigments did not result in any decrease in the use of older ones but rather aided in the expansion of the industry and helped to increase the use of paint for many purposes.

The first of the newer white pigments to be introduced was zinc oxide. This pigment was probably used to a limited extent during the middle ages, but it was not produced in quantities of real importance before the end of the eighteenth century. The manufacture of zinc oxide probably originated in France, largely through the efforts of Courtois. The first commercial factory for the production of zinc oxide was established in France by Le Claire, and from the beginning of the zinc oxide industry, France has continued to be a large producer of this material.

The manufacture of zinc oxide rapidly spread to other countries, and at the beginning of the twentieth century, zinc oxide had become a very important paint pigment and was being manufactured in large tonnage.

Zinc oxide was a valuable addition to the older paint materials, and its characteristics are such that it soon became widely used with other pigments in various paint products and also as a single pigment in many special products, such as enamels, where its physical properties are particularly valuable. The rapid advance in the development of many of these special products has been due largely to the introduction of zinc oxide.

As would be expected with a new material of this kind, the manufacture of zinc oxide increased rapidly and its production has followed the growth of the industry in a very substantial and satisfactory manner.

Lithopone was the next white pigment to become established. It was developed and manufactured toward the end of the nineteenth century and was originally put on the market by J. B. Orr in England.

Lithopone is a very interesting pigment, occupying the rather

unique position of a white pigment, with good hiding power and certain physical properties which make it suitable for use in many paint mixtures, which can be made and sold at a comparatively low price.

Its development has been rapid, due to its low price, and although it is not a durable pigment in paints used for exterior exposure, its use in interior paints has shown remarkable growth, and statistics show that very large quantities of lithopone are used in making interior paint and enamel products.

Lithopone did not replace white lead and zinc oxide to any great extent, because prior to the advent of lithopone comparatively little paint was used for interior wall work. The recent great expansion in interior wall painting was stimulated by the introduction of lithopone, as its good mixing and brushing qualities and low price have enabled the manufacturers to make paints for interior use which are particularly able to compete with other types of interior finish.

Basic lead sulphate is a white pigment which originated in the United States and was first produced by Bartlett in 1870. The method of production used by Bartlett was similar to the present process, the principal difference being in some modifications and many improvements which have been introduced with the growth of the industry.

The consumption of basic lead sulphate in the paint industry was very small up to the end of the nineteenth century, but the twentieth century has witnessed a marked increase in the use of this pigment and it is consumed in considerable amount at the present time although its production is still small when compared with some of the other white pigments. It somewhat resembles white lead in many of its characteristics and has been extensively used in some paint products, usually mixed with other pigments.

Titanium oxide is the last white pigment of great commercial importance to come into the paint industry. It was developed about 1915 and was first marketed in the United States as a composite pigment, mixed and coalesced with blanc fixe, under the trade name of Titanox. Later on, it was put on the market in the form of pure titanium oxide.

The development of titanium oxide pigments was due to modern scientific research, conducted simultaneously by the Titanium Pigment Company of Niagara Falls and the Titan Company, A/S,

of Norway, which has resulted in the establishment of factories in both countries.

Considering the few years titanium pigments have been on the market, their growth has been surprisingly great. Titanium pigments also occupy a unique position in the paint industry because they are pigments with valuable and unusual characteristics which have been used in large amount even though it has been necessary to sell these pigments at a comparatively high price because of the high cost of manufacture.

The most valuable characteristic of titanium oxide is its hiding power, which is several times as great as any of the other commercial white pigments. Hiding power is one of the principal requirements of a paint pigment, and the great hiding power of titanium oxide accounts for the rapid development of the titanium pigments even though these pigments must necessarily be comparatively expensive.

The Early Days in America. During the early days of the colonies before the Revolution, industrial life in America was in its infancy and hardly any attempt was made to produce manufactured products. The early settlers were poor, with very simple tastes, and practically all of their energies were expended in the struggle for existence which made it necessary for them to devote their time to obtaining food and clothing. They were without means to start factories, and what manufactured articles were required for the meager needs of the colonies were readily supplied by importation from Europe. In those days, paint was considered a luxury and not a necessity. Timber was at hand and the only expense in connection with lumber for building purposes was the cost of cutting the trees and hewing the lumber. With such cheap building materials, the cost of preservation by the use of paint was thought to be very high and paint was looked on as a luxury to be used only by the aristocrats.

In 1773, Samuel Wetherill had a small factory in Philadelphia for the manufacture of cotton and woolen fabrics, and in 1778 the firm of Samuel Wetherill and Sons was formed and the business developed until it embraced the importation and sale of different chemical products including white lead and red lead.

In 1804, Samuel Wetherill and Sons erected the first white-lead works in the United States. Considerable jealousy was aroused on the part of the foreign manufacturers when the new enterprise was

started and it has been thought that the fire which destroyed the Wetherill factory soon after its erection was of incendiary origin instigated by the foreign white-lead makers. The factory was rebuilt in 1808 in the face of great opposition on the part of foreign white-lead manufacturers, but Wetherill completed the factory and operations were started in spite of the competition. The foreign white-lead manufacturers then lowered the price of white lead to such a point that the Wetherill factory could not operate at a profit, and they were on the point of failure through competition when

Courtesy of Wetherill and Brother

FIG. 1.—Old print of white-lead factory erected by Samuel Wetherill and Sons in 1808, at the corner of Twelfth and Cherry streets, Philadelphia.

the War of 1812 necessitated the withdrawal of the foreign white-lead manufacturers from the American market. From that time on, Wetherill and Sons was very successful and this company is still making white lead under the present name of Wetherill and Brother.

In 1772 Mordecai Lewis, a merchant and member of the firm of Neave, Harman, and Lewis, was importing and dealing in white lead and red lead. After some time, the name of this firm was changed to Mordecai Lewis and Company and at an even later date to M. and S. N. Lewis. In 1820, M. and S. N. Lewis erected a small factory in Philadelphia for the manufacture of lead products. This company has been in business manufacturing white lead continuously since that date and the business has remained in the Lewis family. This company is still operating and manufacturing lead products under the name of John T. Lewis and Brothers Company, which is the Philadelphia Branch of the National Lead Com-

pany, and the direct descendants of Mordecai Lewis are still associated with the business.

These two factories in Philadelphia, built near the beginning of the nineteenth century, were the first white-lead factories in America. A small white-lead plant was in operation in Pittsburgh as early as 1810, but the total tonnage of white lead produced in this country at the beginning of the war of 1812 was probably less than 1000 tons per annum.

In 1822 Dr. Federal Vanderburg and Dr. Josiah Noyes formed a partnership and began to manufacture white lead, and in 1825 Josiah Noyes, Augustus Graham, and David Leavitt incorporated the Brooklyin White Lead Works, which continued in business for many years, finally being merged with the National Lead Company.

Between 1826 and 1830, the production of white lead increased, and from 1830 to 1850 the white lead industry in the United States grew rapidly, and the development of the paint and varnish industry also increased in importance, as is indicated by the use of different pigments, linseed oil, and other paint materials.

Present Status of the Industry. Manufactured paint and varnish materials, in form ready for the use of the ultimate consumer, as made and marketed in the United States, may be broadly classified as follows:

Dry Pigments
Paste Pigments and Paste Paints
Ready Mixed and Semi-paste Paints
Enamels
Varnishes
Clear Pyroxylin Lacquers
Pigmented Pyroxylin Lacquers

The raw materials used in making these products are obtained from many sources and from many different parts of the world.

Some of the pigments are natural mineral or earth colors, some are made from metals or the ores of metals, others are inorganic pigments made by different chemical processes, and still others are organic colors and dyes, used either in pure form or as composite pigments mixed or combined with inorganic bases.

The paint vehicles consist principally of non-volatile vegetable drying oils and semi-drying oils and volatile turpentine and petroleum thinners.

The paint vehicles are also used in making varnish, and in addition some varnishes require the incorporation of certain resins and fossil gums.

Enamels are similar to paints except that varnishes instead of oils are used for the enamel vehicles.

Pyroxylin lacquers are essentially solutions of nitrocellulose in certain organic solvents. The solutions are liquids which are used in clear form or mixed with different pigments.

The production of the raw materials and the manufacture of the finished products taken as a whole, is a highly technical industry,

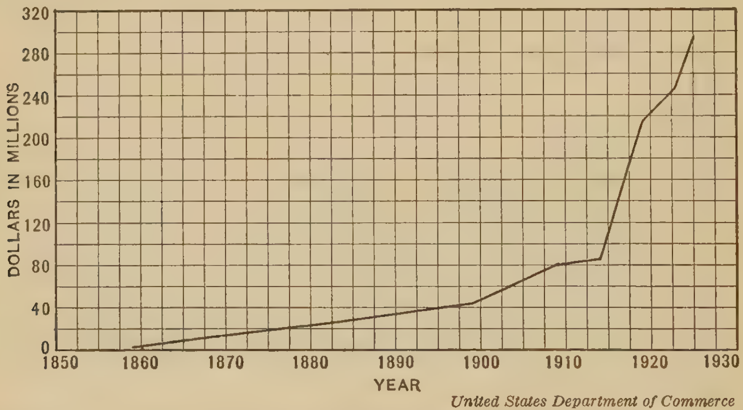


Chart I. — Total annual cost of materials used in paint and varnish industry in the United States.

making use of many chemical and mechanical processes, and depending on certain branches of mining and agriculture as well as on economic conditions which are common to many manufacturing industries.

At the present time there are about 800 manufacturing establishments in the United States which are making paint and varnish as their chief products. These factories represent a capital investment of about $250,000,000 and the products manufactured annually have a value of about $500,000,000. They employ about 35,000 persons, of whom more than 25,000 are wage earners with a total annual wage of approximately $35,000,000.

The cost of materials including fuel, power, and containers is about $300,000,000 annually, and the value added by the manufacturers is nearly $200,000,000, but profits cannot be calculated from

these figures because they do not include a number of expense items such as interest on investment, rent, depreciation, taxes, insurance, and advertising.

The accompanying graphs show the range in cost of materials and value of manufactured products for a number of past years.

The annual production at the present time is approximately 210,000 tons of paste paints, comprising about 130,000 tons of pure white lead in oil, 12,000 tons of combination or graded whites, 3000 tons of zinc oxide in oil, and 65,000 tons of other paste paints;

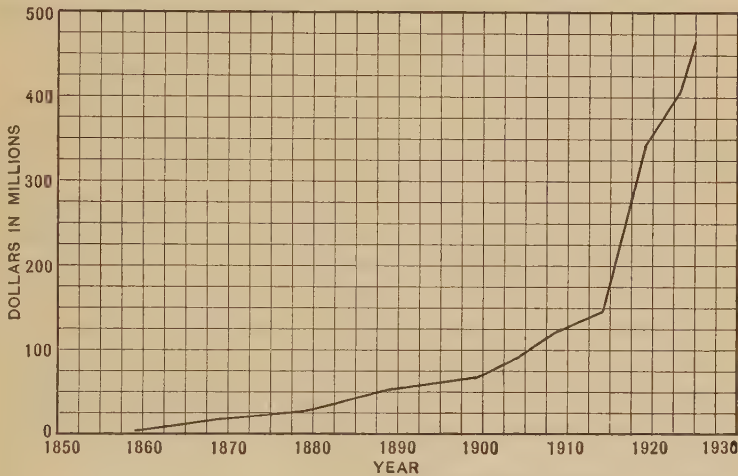


CHART II. — Total annual value of all products made in the paint and varnish industry in the United States.

90,000,000 gallons of ready-mixed and semi-paste paints, including enamels; 75,000,000 gallons of varnishes and japans; and 20,000,000 gallons of pyroxylin (nitrocellulose) varnishes or lacquers.

There has been a steady increase in the production of pigments, as shown in the graphs for white lead, zinc oxide, and lithopone. The prices of these pigments have varied considerably, as indicated in the graphs, the value generally following the prices of the metals which, either in virgin or by-product form, are used for making them.

Increase in production is noted in the graphs for the different paint and varnish products, indicating that the industry, as a whole, is progressing in a satisfactory manner.

Pyroxylin lacquer deserves special mention at this time because it is a new branch of the paint industry which has been growing with great rapidity. In 1919, the production of pyroxylin lacquer was only about 500,000 gallons, and a study of the graph shows that the use of this material has increased to such a surprising extent that the present production is in excess of 20,000,000 gallons per annum.

Pyroxylin lacquer has been known and used to a slight extent for many years, but the nitrocellulose available in the past was not suitable for making satisfactory lacquers because of the high vis-

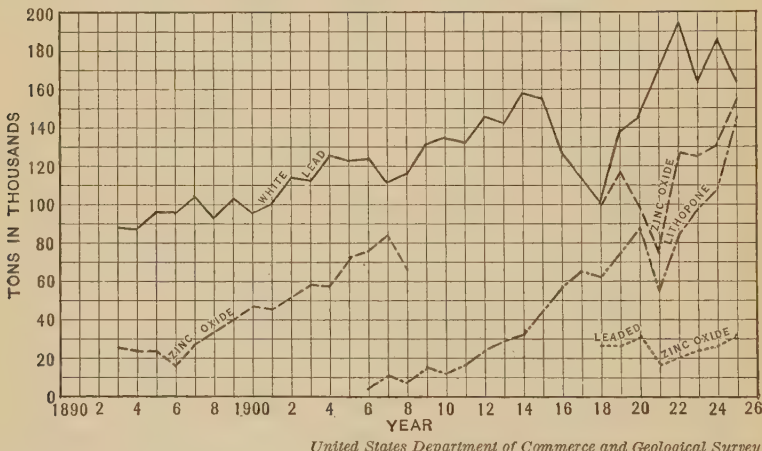


Chart III. — Total annual production of white pigments in the United States (no zinc oxide statistics available 1908–1918).

cosity of solutions containing a comparatively small proportion of nitrocellulose. Recent improvements in the manufacture of nitrocellulose (nitrated cotton) have made it possible to obtain this material in such form that a fairly large proportion may be dissolved in the solvents without causing the solutions to become excessively viscous, and this new type of nitrated cotton has been one of the principal factors in the rapid development of lacquers of this kind.

Because of the rapid evaporation rate of the solvents, pyroxylin lacquer dries very rapidly, and for this reason is difficult to brush and is usually applied by spraying machines. A very large percentage of the lacquer which is manufactured is used to finish motor cars, and such lacquer is used also on furniture in con-

siderable quantity. During the last two years, brushing lacquers with a slower evaporating rate are beginning to appear on the market.

Factory Operations. Paints have always been made by mixing the pigments and vehicles together so as to form products which have many of the characteristics of liquids but which, after being spread in thin films, will dry, by oxidation or evaporation or both, to hard elastic solids.

In the early days of the industry, the operation of mixing the pigments and vehicles was performed in a very crude way, but as

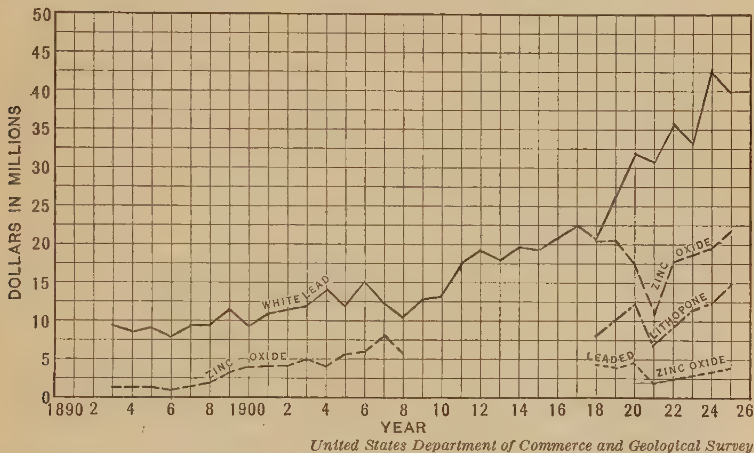


CHART IV. — Total annual value of white pigments produced in the United States (no zinc oxide statistics available 1908–1918).

the industry developed, and as general mechanical operations became perfected, the paint industry kept in close touch with the general progress and not only utilized the standard machinery which is common to many industrial operations but also developed special equipment for the particular needs of paint manufacture.

Today the paint factories are using the most modern handling, conveying, grinding, mixing, drying and packing machinery, with the result that the labor cost is reduced to a minimum and the finished products are uniformly of standard quality.

Much of the handling, drying, and packing machinery used in the manufacture of paints is of the same general type as the machinery used for similar purposes in other industries, and of course the problems of generation and transmission of power are common to

nearly all factories, and the paint factories utilize standard equipment for such purposes.

The paint factories have developed special machinery and equipment for grinding and mixing paint products, but although at the present time such machinery and equipment is really special in the paint industry and is designed and made specially for paint manufacture, many of the machines have been taken from other industries.

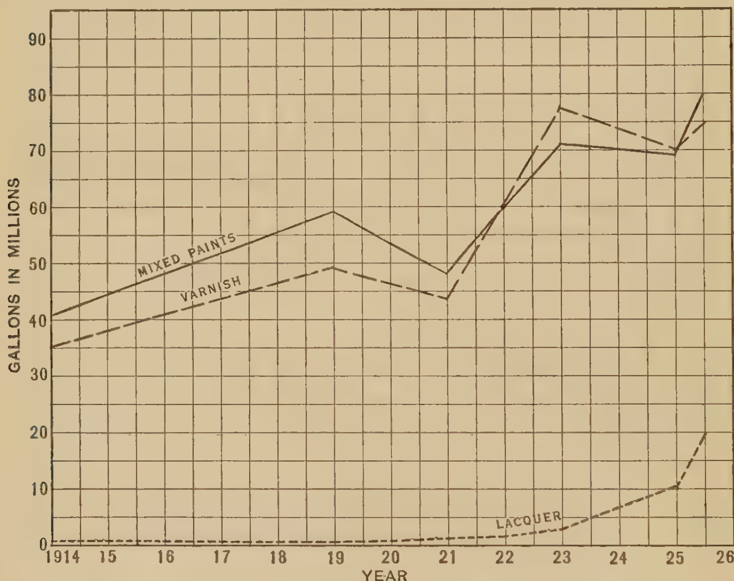


CHART V. — Annual production of paint and varnish finished products in the United States.

The preliminary mixing of the dry pigments with the liquid vehicles is known technically as grinding. This term implies both a reduction in the particle size of the pigment and a thorough incorporation of the dry-pigment particles with the liquid vehicles. The usual procedure is to first grind together the dry pigments with sufficient liquid vehicle to produce a fairly thick paste. The paste must be further reduced or thinned with liquid vehicles to produce paint of brushing or spraying consistency, and this mixing operation may be performed by the painter or may be carried out in the paint factory on a large scale.

In general, four different types of machines are used for grinding, the oldest types being the chaser or edge runner mill and the horizontal Buhr stone mill. A much newer type is the roller mill, and the last machine to be adopted by the paint industry for this purpose is the ball or pebble mill.

The chaser or edge-runner mill has been used for centuries for grinding grain and other materials. It consists essentially of a

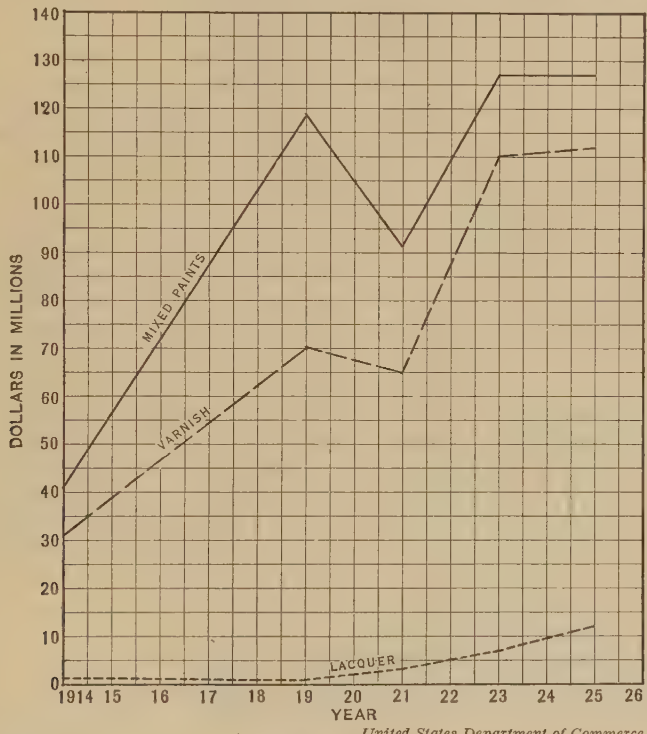


CHART VI. — Annual value of paint and varnish finished products in the United States.

heavy stone or metal vertical wheel which revolves in a horizontal pan at slow speed. This type of grinder is one of the oldest machines used in the manufacture of paint and in its modern form, as specially made for the grinding of paint products, is usually constructed of cast iron and is often arranged so that the runner, as well as the central shaft, is positively driven.

The Buhr stone mill has also been copied from grain-grinding

machinery and is probably the oldest contrivance used for that purpose. The first form probably consisted of two stones between which the kernels of grain were crushed to meal or flour. This type of mill consists essentially of two flat horizontal stones, one fixed and the other rotating at fairly high speed. Such mills are still used for grinding grain, but their adaptation to the grinding of paint products has resulted in many changes, and the modern Buhr stone mill as used in the paint factories is a special paint-grinding machine. Some of these mills as used in the paint factories are very large and are ruggedly constructed because considerable power is required to drive them when they are grinding thick and sometimes viscous paint mixtures. One of the improvements in Buhr stone mill construction for which the paint industry is responsible is the water cooling of the fixed stone by circulating water through pipe coils embedded in the stone.

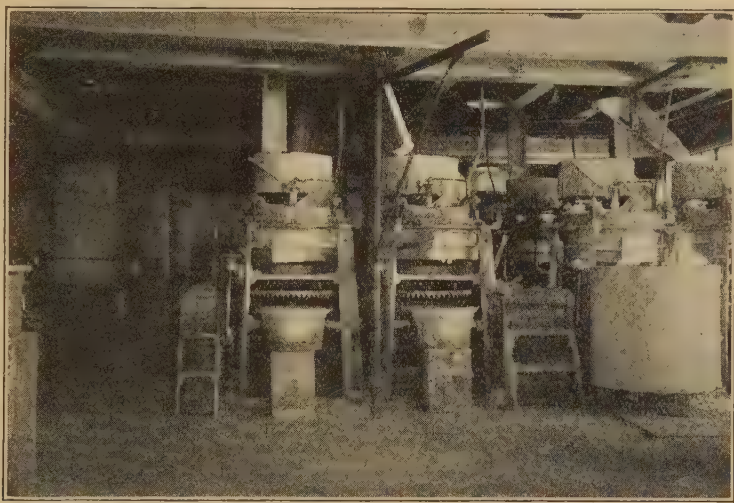
Courtesy National Lead Company

Fig. 2.—Modern white lead factory showing white lead in oil Buhr stone grinding mills.

The roller mill usually consists of three horizontal cylinders or rolls so arranged that they may be carefully adjusted with respect to each other. The three rolls rotate rapidly at different speeds

and the paint products in paste form, which have been given a preliminary treatment in a chaser or mixer, are passed through the rolls. The roller mills used in the United States are almost always constructed with hollow steel rolls, although in England and in Europe stone rolls as well as steel rolls are found. The steel rolls are frequently water cooled to prevent excessive heating of the materials which are being ground.

The ball or pebble mill is a horizontal cylinder rotating at slow speed in which are placed a large number of pebbles or metal balls.



Courtesy John W. Masury and Son

FIG. 3.—Modern paint factory, showing grinding and mixing machinery for mixed paint.

When this mill is used, it is the general practice to add the dry pigment and most or all of the liquid vehicle at one time. The rotation of the mill therefore performs, in a single operation, the grinding and incorporation of the dry pigment and vehicle and the thinning to paint consistency.

When paint is to be made by the further thinning of thick pastes with an additional amount of liquid vehicle, the final thinning or mixing operation is usually performed in a large vertical cylindrical steel tank equipped with mechanically operated mixers or agitators.

The modern paint factory is an industrial establishment where every detail of transportation, building design, labor market,

source of raw materials, power, cost, and other essential features has been carefully considered.

In general, the raw materials and finished products of the paint industry are heavy commodities, having considerable weight in comparison with their value, and transportation facilities are of primary importance. A factory site should have direct railroad connection or deep water or both as long truck hauls are costly and often prohibitive for materials and products of this kind.

Building design is important to simplify operations, permit the use of the most advantageous machinery, and reduce fire risk to a minimum.

Even when the most modern machinery is used, considerable labor is required in paint factory operations, and a good labor market, where efficient labor can be obtained at a reasonable price, is very desirable. Satisfied labor, which results in small labor turnover, is an important consideration and this condition may often be secured by selecting a proper factory location.

Exports and Imports. Most of the raw materials used in the manufacture of paint and varnish and practically all finished paint and varnish products are subject to fairly high import duties, a condition which has greatly restricted the importation of such materials. Most of the materials which are imported in any quantity are those in which exceptional quality or particularly low cost of manufacture cannot be duplicated in the United States. The imported materials consist principally of mineral pigments and lithopone. The imports of finished paint and varnish products are very small.

Labor costs in the United States are very high as compared with the remainder of the world, and it would seem as though the selling of American-manufactured products in foreign markets would be very difficult, but efficient factory operation combined with large scale production, and in some cases the use of imported raw materials in bond without the payment of duty, have made it possible for the American paint and varnish manufacturers to secure a fairly large export business.

The latest export and import statistics obtainable are for the year 1925. The figures for paint and varnish materials were as shown in the tables on the opposite page.

The total value of exports exceeded the total value of imports by $15,274,811, showing a large export trade balance.

EXPORTS DURING 1925

Product	Pounds	Gallons	Value
White Lead	13,663,309		$1,293,168
Red Lead	1,604,497		183,591
Zinc Oxide	21,710,048		1,503,561
Lithopone	2,573,354		132,771
Mineral Pigments	31,264,521		902,833
Bone Black and Lampblack	3,805,340		249,613
Carbon Black			
Other Chemical Pigments	6,525,922		760,106
Ready-Mixed Paints		2,236,847	4,657,782
Enamel Paints	2,662,780		882,451
Other Paints	11,437,948		2,363,353
Oil Varnishes		712,003	1,279,373
Other Varnishes		394,637	745,650
Total Value			$18,510,021

IMPORTS DURING 1925

Product	Pounds	Gallons	Value
Ochres and Siennas	20,138,814		275,020
Other Mineral Pigments	82,591,011		934,821
Lithopone and Other Zinc Pigments	15,538,845		719,877
Other Chemical Pigments			735,094
Paints, Stains, and Enamels	1,557,970		519,156
Varnishes		19,000	51,242
Total Value			$3,235,210

The largest export trade was with the United Kingdom of Great Britain and Ireland and the second largest was with Canada.

The following table shows the value of paint and varnish products which were exported to various countries to the amount of $1,000,000 or over:

EXPORTS DURING 1925

Country	Value
United Kingdom	$3,270,758
Canada	2,638,595
Cuba	1,734,293
Argentina	1,197,655

Economics. The paint industry is highly competitive, and while under most of our government administrations there has been sufficient tariff protection to eliminate severe foreign competition, the domestic competition is very keen. Successful operation requires the exercise of most careful judgment in the selection of factory location and the purchase of raw materials, combined with the greatest efficiency and economy in factory and business organizations.

In selecting factory locations, the principal considerations are transportation, source of raw materials, and market for the finished products. Of these various items perhaps the market for the products is the most important. Paint and varnish products are consumed mostly in communities where there is the largest concentration of population and property investment, and for this reason the paint and varnish factories are found mostly along the middle Atlantic seaboard and in the east-north-central zone of the United States, which includes the states of Ohio, Illinois, Michigan, Indiana, and Wisconsin. Each of these districts contains about the same number of establishments, and about one third of the factories of the United States are found in each district.

These localities represent the largest domestic markets which are the most important because the export business is only a small portion of the total business of the industry.

The availability of raw materials has some influence on factory location, which perhaps accounts for some of the establishments in such cities as Milwaukee and St. Louis, but, generally speaking, the raw material supply is secondary to proximity to the market, and availability of raw materials, while usually existing in manufacturing districts, is incidental rather than an influencing factor in the selection of factory location.

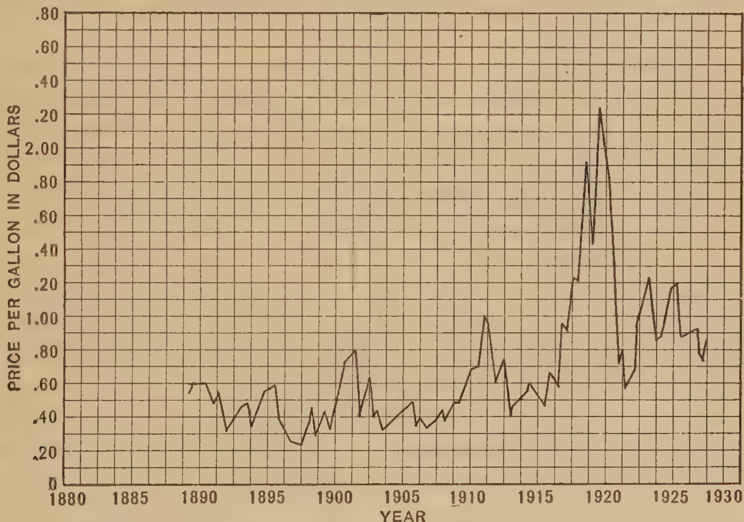
Localities which are centers of population and constitute the greatest domestic markets are usually also centers of production or distribution of raw materials.

Domestic pigments are produced mostly in the east and middle west and imported pigments are largely received at ports on the Atlantic seaboard.

Linseed oil is made from flaxseed, which is grown extensively in the northwest, and a number of linseed oil factories are located in the east-north-central district within easy shipping distance of the many paint and varnish factories in the same district.

Much of the linseed oil used in the United States is made from flaxseed imported from Argentina, and the Atlantic seaboard has become the logical location for factories crushing Argentine seed.

China wood oil (Tung oil) and many other oils and resins are imported and ports of entry offer the greatest facilities for supply of such materials. Practically all of the China wood oil comes from China, but it is interesting to note at this time that a very ambitious attempt is being made to grow, in some of the southern states, the trees from which the China wood oil bean is obtained.



Courtesy Paint Oil and Chemical Review

Chart VII. — Linseed oil prices in the United States. (1889–1925 prices were for gallons of $7\frac{1}{2}$ pounds. Beginning 1926 quotations were for pounds.)

This work is apparently meeting with considerable success, and it seems probable that, in the not distant future, a large part of the China wood oil consumed in the United States will be obtained from domestic supply.

The wise purchasing of raw materials is very important as market conditions and prices vary greatly. This is well illustrated by the fluctuations in the price of linseed oil shown in the accompanying graph. Not only the price trend but also the market conditions must be considered so as to insure reasonably prompt delivery of finished products at all times without carrying a large excess of raw material in falling markets.

Organization. The paint and varnish industry is exceptionally well organized, but the organizations are of the most desirable type, as they have always operated to promote coöperation, the dissemination of information, and general friendly relations and have never functioned to maintain excessive prices or form combinations in restraint of trade and competition.

A brief history of the organizations which have been of importance in the industry might be of interest.[1]

The National Paint, Oil and Varnish Association was organized in 1888 and was incorporated in 1915. It is made up of the proprietors and executives of most of the large paint and varnish manufacturing companies and also includes in its membership many large distributors and manufacturers of supplies.

The Paint Grinders' Association of the United States was organized May 8, 1899 and the name was changed to Paint Manufacturers' Association of the United States, in 1907.

The National Varnish Manufacturers' Association was formed, November 9, 1903.

The Paint Manufacturers' Association and the National Varnish Manufacturers' Association were consolidated October 11, 1926, under the name of American Paint and Varnish Manufacturers' Association, which was incorporated under that name in December, 1926. This Association consists of the executives of many of the paint and varnish manufacturing concerns and many of its members are also members of the National Paint, Oil, and Varnish Association.

The Federation of Paint and Varnish Production Men's Clubs was organized June 15, 1922. It consists of factory managers, superintendents and technical men in the paint and varnish industry. The Federation is made up of eleven production mens' Clubs existing at the time of the formation of the Federation as follows:

California Paint Superintendents Club
Cincinnati & Dayton Paint & Varnish Production Club
Cleveland Club of Paint Superintendents
Detroit Paint & Varnish Production Men's Club
Louisville Superintendents Club
New England Paint & Varnish Production Club

[1] From information furnished by G. B. Heckel, Secretary-Treasurer, American Paint and Varnish Manufacturers' Association, in a private communication.

New York & New Jersey Paint & Varnish Production Club
Paint & Varnish Production Men's Club of St. Louis
Paint & Varnish Superintendents Club of Chicago
Paint & Varnish Superintendents Club of Philadelphia
Toronto Club of Paint & Varnish Superintendents

Federal Specifications for Paints and Varnishes. The Federal Specifications Board has been very active in compiling and adopting specifications for paint and varnish materials for use by Government Departments, and the following statement, prepared by N. F. Harriman, Vice-Chairman, Federal Specifications Board, is of interest.

With the installation of the Bureau of the Budget in 1921, the President of the United States assumed for the first time in the history of this country his position of responsibility as Head of the Business Organization of Government. One of the principal questions before him was the necessity of setting up certain agencies for the coördination and control of governmental routine business.

By direction of the President, there was established a number of coördinating boards relating to certain specific activities of government, namely, the Federal Specifications Board, Federal Purchasing Board, Federal Liquidation Board, Federal Traffic Board, Federal Real Estate Board, and Interdepartmental Board of Contracts and Adjustments. The Federal Specifications Board was organized under authority of Circular #42, Bureau of the Budget, dated October 10, 1921, in which it was stated that the establishment of the board was for the purpose of coördination and economy in the procurement of materials and services used by the Government under specifications prepared by the various branches thereof, to avoid duplication of effort and for the better utilization of industries. The duties of the Federal Specifications Board were to compile and adopt standard specifications for materials and services and to bring the Government specifications into harmony with the best commercial practice wherever conditions permitted, bearing in mind the desirability of broadening the field of supply.

Each department and establishment purchasing materials and supplies in accordance with specifications designated a representative to serve as a member of the Board. The initial meeting was held on October 31, 1921, at which time an Executive Committee,

consisting of the representatives from the ten Executive Departments, the Panama Canal, and the General Supply Committee, was formed as being more compact for the routine handling of business of the Board.

The procedure adopted for the consideration of the specifications is as follows: The need of specifications for a given article or material, for either technical or business reasons, is fully considered by the Executive Committee and the subject is then referred to a technical committee composed of the Government experts in the particular subject, for consideration of all existing Government or commercial specifications. A specification is selected or written, which will be suitable for the uses of all departments and establishments of the Government. The coöperation and advice of interested commercial and industrial concerns is requested and their recommendations are fully considered by the technical committees. The specification as agreed on by the technical committee is then submitted to all departments and establishments of the Government, through their respective representatives on the Federal Specifications Board, for comment and criticism. At the same time, copies of the proposed specifications are submitted to the American Engineering Standards Committee with a request for their assistance in securing comment and criticism from the various interested engineering and technical societies all over the country. All criticisms received are referred back to the respective technical committees for consideration of their merits. When the specification is finally agreed upon, it is promulgated by the Federal Specifications Board as official Government Standard for use in connection with the purchase of material covered by the specification.

The Circular establishing the Federal Specifications Board states that the specifications adopted and promulgated by the Board shall be binding upon and govern all Departments and Independent Establishments of the Federal Government, and was issued by the Director of the Bureau of the Budget, by direction of the President.

The organization of the Federal Specifications Board Technical Committee on Paint is described in a private communication from P. H. Walker, Chairman, Technical Committee on Paint, as follows:

The Interdepartmental Committee on Paint Specification Standardization preceded the organization of the Federal Specifications Board.

After the Armistice was signed the War Industries Board requested the Department of Commerce to attempt to prepare standard specifications for paint materials. As a result of this, a conference of the representatives of the interested branches of the Government Service was held on February 26, 1919. This conference recommended that the Interdepartmental Committee on Paint Specification Standardization be organized. The committee was organized and it at first consisted of one representative each of the War, Navy, Interior, Treasury, Post Office, Agriculture, and Commerce Departments, the Panama Canal, Railroad Administration, Housing Corporation, and Paint Manufacturers' Association. There were, of course, some changes made in the personnel of the Interdepartmental Committee on Paint Specifications Standardization between the time of its organization and the organization of the Federal Specifications Board. When the Federal Specifications Board was organized, the Interdepartmental Committee on Paint Specifications Standardization was constituted the Technical Committee on Paints of the Federal Specifications Board.

The Interdepartmental Committee on Paint Specification Standardization had no authority to compel the adoption of its specifications, and therefore issued recommended specifications which could be used or rejected by any interested branch of the Government Service. It cannot therefore be said that there were any United States Government Specifications for paint materials until after the organization of the Federal Specifications Board, which has the authority to adopt U. S. Government Master Specifications.

Other Standard Specifications. The American Society for Testing Materials is a technical society with a very large membership consisting principally of technical men representing both producing and consuming interests, of many industries. The principal function of the Society is the preparation and adoption of standards for various materials and the work of the Society is carried on largely by a number of Standing Committees.

Committee D–1 on Protective Coatings for Structural Materials confines most of its activities to paint and varnish materials. The Committee has about one hundred and eighty members who broadly represent the paint and varnish industry. Committee D–1 has been responsible for the adoption by the Society of many standard specifications for materials, standard methods of test,

and standard definitions of interest and value to the paint and varnish industry.

The Committee was organized in 1902 and was originally known as Committee E. In 1910 the title was changed to Committee D–1.

In 1924 the Paint and Varnish section of the American Chemical Society was formed and in 1927 it became the Paint and Varnish Division. Many of the chemists in the paint and varnish industry belong to the Division, which is doing some very good work and is bringing out a number of excellent papers which are of great scientific interest to the industry.

Conclusion. It is sometimes said that the degree of industrial civilization which a nation has attained may be measured by the amount of sulphuric acid which it consumes in proportion to its population. The consumption of sulphuric acid is taken as a measure of progress because it enters into so many products and processes which are important in maintaining the standards of modern national life.

For a similar reason, the consumption of steel has also been used as a barometer of national development, but while the use of sulphuric acid and steel do undoubtedly bear some relation to the advance of civilization, they are both special materials, and while they are used for very important purposes strongly indicative of progress, their use is, nevertheless, somewhat limited.

Paint is a material which is used in the broadest possible way to preserve and decorate buildings, industrial structures, and many other objects of value, and it may well be said that the consumption of paint is a most comprehensive measure of a nation's advance, and proportional increase in consumption of paint is an indicator of a nation's continued development.

The United States may well be proud of the fact that each generation has shown a greater appreciation of the value of paint and the continued increase in the consumption of this material is satisfactory evidence of national, industrial, commercial, and esthetic progress.

CHAPTER XVI

THE AMERICAN PETROLEUM INDUSTRY

By George Ward Stocking [1]

The Significance of Petroleum in Modern Industrial Life. In 1895 there were four automobiles in the United States. In the same year the English law prohibited motor cars from running on public roads faster than four miles an hour, and even at that pace it required that a man precede them waving a red flag as a warning of danger. In 1926 in a single day in New York City 24,170 motor cars crossed Forty-second Street as they streamed up and down Fifth Avenue, stopping and starting in regular succession as though automatically controlled by the blinking of the double-eyed bronze towers which stand as guardians of the public safety. At the same time the story is told of a motorist rebuked by a traffic policeman on an important Eastern highway for retarding traffic. "But," said the motorist indignantly, "I was going thirty-five miles an hour." "Go sixty!" commanded the cop.

Such amazing changes in a period of three decades in the traffic problems of modern society reflect literally the speed with which we are traveling. Material developments are proceeding at a pace never before equaled in the history of industry. The automobile, the airplane, the submarine, an oil-fed navy and merchant marine, oil-burning locomotives — all made possible by the development of the American petroleum industry — have indeed revolutionized the modern transportation problem. Petroleum has enabled man to run by land at a speed of 180 miles per hour, and to skim over the earth's surface on wings at a speed of 250 miles per hour. With its aid he can with ease and security cruise at a depth of 100 feet below sea level through a watery highway, and by the same means he has been able to mount into the air 41,000 feet, twelve thousand feet higher than Mount Everest, whose summit British explorers have long endeavored to attain.

[1] University of Texas.

Such striking illustrations of the specific achievements made possible by petroleum suggest something of its importance and its relation to industry at large. The position of petroleum in the industrial world may be more precisely and summarily indicated by the fact that petroleum refining, as judged by the wholesale value of its products, ranked sixth among all the manufacturing industries in the United States in 1923, the last year for which figures are available. In that year the refineries of the country consumed 601,748,000 barrels of crude petroleum and 35,155,000 barrels of distillates which were put through a secondary refining process. In addition, the natural-gas gasoline plants of the country manufactured 15,949,000 barrels of gasoline from natural gas produced in conjunction with crude oil from oil wells. The total value of the refined products secured from these raw materials (crude petroleum, distillates, and natural gas) was $1,793,700,000. It is in terms of the major refined products that the importance of the petroleum industry is adequately to be comprehended.

Petroleum possesses peculiar value to society because it is the sole commercial source of gasoline, which has made possible the spectacular development of the motor-driven vehicle; because it yields lubricants, without which the wheels of industry literally could not turn; because it supplies the world with kerosene, which outside of cities and highly industrialized areas still remains the chief illuminant; and finally, because it yields fuel oil, which has become in certain sections of the country and for certain uses an essential, almost indispensable source of power.

The importance which gasoline has come to play in our industrial and social life has already been suggested, but it may perhaps be even more forcefully indicated by a brief résumé of the details of motor-car development. From the simple beginnings pictured in the opening lines of this chapter, with four automobiles in the entire United States, the annual production of motor cars has shown an almost uninterrupted increase, until the year 1925 witnessed a total American production of 4,336,262 cars and a motor vehicle registration for the entire United States of 19,954,347 — an average of one motor car for every 6.5 persons. California, with its splendid system of highways and its climate ideal for motoring, boasts of one motor car for every 3.2 persons. The Census of Manufactures for 1923 indicated the manufacture of motor vehicles as judged by the wholesale value of its products ($3,163,327,874) to

be the most important single manufacturing industry in the country at large. In 1896 gasoline was a waste product in the manufacture of kerosene. To furnish the motive power for our tremendous automobile fleet, the refineries of the country in 1923 produced 7,332,329,000 gallons of gasoline, representing by volume approximately 28 per cent of the total crude oils and distillates run to the stills, and by value of the total refined products approximately one half.

While the demand for lubricants since the beginning of the present century has been continuously less important from a quantitative point of view than the demand for gasoline, the significance of lubricants as a factor in industrial progress has been perhaps greater. The closing decades of the nineteenth century witnessed a marked increase in the use of machinery incidental to the development of large-scale production and the expansion of industry made possible in large part by the rapid extension of our railway system. Had it not been for the American petroleum industry, the stupendous industrial development of the nineteenth century would scarcely have been possible. Without lubricants the wheels of industry will not long turn. The important rôle which lubricants play in efficient functioning of modern machine processes is frequently ignored or merely taken for granted. Their real significance is indicated in an address by Dr. George Otis Smith before a recent meeting of the American Iron and Steel Institute:

> In our attention to the generation of power to meet the needs of industry and transportation, we give too little thought to the unique function of oil — that of saving power. Machinery without lubrication is unthinkable; adequate lubrication saves energy and makes it available for use as well as adds to the life of the machine.

It is true that there are other sources of lubricating oils than crude petroleum. Various kinds of animal and vegetable fats and such solid substances as graphite supplied the limited demands for lubrication prior to the commercial utilization of petroleum and even yet find their way in small quantities into lubricating uses. The rôle which they now play in industry is negligible, however, as compared with that of mineral-oil lubricants. In truth, there seems to be no quantitative substitute for mineral lubricating oils, and their consumption may be expected to show a steady increase with the passing of time. There is reason to believe

that a supply of vegetable oils adequate to meet all our needs for lubrication would require an acreage which would involve a serious inroad on our food supply.

To meet the needs of industry at large for lubricating oils, the refining industry in 1923 yielded 1,150,652,000 gallons of lubricants, representing by volume approximately 4½ per cent of the crude oils and distillates run to the stills, and by value of the total refined products approximately 11 per cent.

Until the opening of the twentieth century the demand for kerosene furnished the driving force in oil production. Very shortly after the discovery of the first commercial oil well, kerosene became the major source of illumination for the entire civilized world, and American oil wells have supplied by far the largest proportion of this illuminant. In recent years, however, electricity and artificial gas have made serious inroads into the market for kerosene as an illuminant. The electric light has completely superseded the oil lamp for lighting purposes in our cities, and more and more high-tension electric lines and electric farm-lighting units are supplying the rural districts with superior illumination. The supremacy of kerosene as an illuminant still remains uncontested in the remoter corners of civilization, however. As its market for illuminating purposes has been narrowed, moreover, its market as a source of power has been greatly broadened as the farm tractor has come into greater use; and more recently kerosene has taken on a new importance as a competitor of coal for domestic heating purposes. To meet these various demands for kerosene, the refineries of the United States in 1923 yielded 2,238,900,000 gallons of kerosene, representing by volume approximately 8 per cent of the total crude oil and distillates run to the stills, and by value of the total refined products approximately 12 per cent.

Fuel oil, the fourth major product of crude petroleum, ranks even more important from a quantitative point of view than do any of the three foregoing products. In 1923 the refineries of the country yielded 11,976,397,000 gallons of fuel oil, representing by volume approximately 45 per cent of the total volume of crude oil and distillates run to the stills (an amount larger than that for gasoline, lubricants, or kerosene), and by value approximately one fifth that of all products, ranking ahead of both kerosene and lubricating oils in this respect. Notwithstanding its first rank when judged in terms of volume of output and its second rank

when judged by value of product, fuel oil may well be placed last in the discussion of the relative importance of refined petroleum products; for throughout the history of oil production it has remained in an economic sense a residue after the country's demand for other products has been satisfied. This residue has been found valuable as a fuel for steam-raising purposes and it has been disposed of in this manner. Confronted at the time of its appearance in industry with a fuel market in which coal had already thoroughly established itself, fuel oil has had to force its way. Its liquid oiliness has been a distinct advantage in its fight for recognition in the fuel market and has made smooth its entrance therein.

Liquid fuel has distinct advantages over coal. It can be handled for approximately one fourth the cost necessitated by coal, reduces steaming time by approximately one half, requires only three fifths the storage space, has a greater value per ton, undergoes 9 per cent less combustion loss, and yields 10 per cent greater boiler efficiency than does coal. With the tremendous increase in the production of oil in recent years, the supply of fuel oil has become so great as to demand that the organized efforts of the petroleum industry secure a place for it in the fuel markets. Because of the superior fuel qualities which oil possesses, this effort has been well rewarded.

In three different directions fuel oil has made marked inroads on the field of coal, — in transportation, in industry, and in domestic household heating. In 1925 almost 70,000,000 barrels of fuel oil were consumed by locomotives on the lines of 147 different railway companies. Approximately one half of this amount, however, was consumed by two major lines operating in the southwestern part of the United States. The 1925 consumption of fuel oil by railway locomotives represented an increase of more than 100 per cent over the consumption for 1921. Precise figures for the amount of fuel oil consumed for domestic heating purposes are not available, but common observation indicates a rapid increase in such consumption. Fuel oil consumed in automatically controlled domestic heating plants eliminates many of the worries of the home furnace man, and, as it has found its way into the home, it beckons more and more alluringly to a far larger group of householders who have heard glowing tales of its advantages. It may well prove to be holding out a false hope, however, for the use of fuel oil in the home as well as its use in railway locomotives may

be regarded as wasteful from the social point of view. Coal, while less satisfactory in many respects than fuel oil, is available in far larger quantities. The United States possesses coal supplies adequate to meet the needs of industry for generations to come. The supply of oil seems likely to prove far less adequate. Fuel oil is capable of yielding additional gasoline and lubricants for which there are no satisfactory substitutes and, with a growing demand for these products, its general consumption as fuel would seem indefensible. In certain sections of the country, notably the state of California, lack of a convenient coal supply has resulted in the entire industrial structure's having been built upon fuel oil as a base. The consumption of fuel oil in industry in these sections may perhaps be regarded as essential, for a transition from fuel oil to coal would involve readjustments of such proportions as to disturb seriously the entire industrial and social life of the area.

The consumption of fuel oil may well be reckoned indispensable in one other use; namely, in the navy as a measure of national defense and in the auxiliary merchant marine. Admiral Lord Fisher, whose forecast of more than a generation ago regarding the use of petroleum for naval purposes has been so abundantly fulfilled, expresses the present-day importance of fuel oil in this regard as follows:

> The use of fuel oil increases the strength of the Navy . . . thirty-three per cent because it can re-fuel at sea off the enemy's harbors. . . .
>
> With two similar dreadnoughts oil gives three knots more speed . . . and speed is everything.
>
> Oil for steam raising purposes (*i.e.*, burning under boilers) reduces the present engine-room and boiler-room personnel some 25 per cent, and for internal combustion engines would reduce the personnel over 60 per cent.
>
> It is criminal folly to allow another pound of coal on board a fighting ship.

In response to Admiral Fisher's warnings and the experience of the recent World War, not only have the navies of the world gone largely on a fuel-oil basis but the merchant marines likewise are turning rapidly to its use. The United States Shipping Board is definitely committed to an oil-burning policy. By 1924, 85 per cent of the tonnage under the control of this organization was on an oil-burning basis.

Oil for fuel! Oil for lubricants! Oil for motor power! Oil for more than a score of by-products, which cannot be considered here

for lack of space! Oil has indeed come into its own. In truth, oil has so woven itself into the fabric of our industrial and social life that there seems no doing without it.

Historical Development of the Oil Industry. To such a significant position oil has arisen from humble origins. The existence of petroleum seems to have been known since antiquity. It is even presumed to have been turned to useful account by the ancients in their building operations. We are told that the builders of Noah's Ark and the Tower of Babel had available in petroleum a substance appropriate as a substitute for modern plasters and cement. Excavations in Assyria and Babylonia have revealed building material covered with an asphalt cement. Petroleum seems to have figured more prominently, however, in the spiritual life of antiquity than in its material development. The sacred "everlasting" fires to which the Parsees made their religious pilgrimages from India and in whose worship they built the Temple of Surakany are presumed to have had their origin in the petroleum-saturated soil on the Russian shore of the Caspian Sea, which even yet will burst into flames upon the application of a match.

In the New World prior to the coming of the white man, petroleum seems to have played its major rôle as a medicament in the simple pharmacopœia of the American Indian. The American settlers, on encountering the crude, evil-smelling liquid in their search for salt in drilled wells, regarded it at the outset as a nuisance. The rapid exhaustion of the whale fisheries and the invention of the modern oil-burning lamp by the middle of the nineteenth century, however, made petroleum a social and industrial necessity. A refining technique had been worked out by 1847 by James Young in Scotland for the distillation of kerosene or, more properly, "coal" oil from coal and shales. This technique was soon afterward applied in Europe to the refining of crude petroleum secured from natural deposits in Galicia, Roumania, Alsace, and Northern Italy. Production of the crude product in these areas proved inadequate to meet the rapidly growing demand for kerosene, an illuminant far superior to the tallow candles and whale-oil lamps of olden days. To fill the breach between a waning petroleum supply and an incipient world demand for an illuminating oil, the American oil industry was created.

As early as 1854 two enterprising business men secured a sample

of crude petroleum from oil seeps in Western Pennsylvania, near what had come to be known as Oil Creek, and had it analyzed by Professor Silliman of Yale University. In this analysis Professor Silliman pronounced the crude substance valuable as a source of both a good illuminant and a good lubricant. Out of this initial effort there developed the Pennsylvania Rock-Oil Company. The direct activities of this company seem to have accomplished little. In 1859, however, James M. Townsend, a New York lawyer, who was one of the original stockholders of the company, secured the services of the now famous Colonel E. L. Drake to make another attempt in the Oil Creek region to obtain oil in commercial quantities. At the outset small quantities of oil were secured from seeps and sold at twenty dollars per barrel. In the hope of increasing production it was decided to drill a well and, if possible, find the source of the oil. This endeavor encountered serious obstacles. After four months of continuous digging, solid rock was struck. To pierce this, it was necessary to install a steam drilling machine, the cost of which involved a heavy financial drain upon a now almost bankrupt enterprise. On August 23, 1859, success crowned Drake's endeavors and oil was struck at a depth of sixty-nine feet, the golden liquid half filling the hole. A small pump was installed and the well yielded about one thousand gallons of oil daily. The commercial value of the daily output was approximately $500, a tremendous income when judged by the standards of the time.

The unexpected tapping of this hidden source of wealth called into the new-born oil industry a host of explorers and speculators in an enthusiastic search for liquid gold. Wells were drilled in areas adjacent to the discovery well, and in June, 1861, the first well with a natural flow — the "Fountain" well — was completed with a daily production of three hundred barrels. In September of the same year a well with the tremendous daily output of 2500 barrels was completed. The total production in the United States in 1860 was 500,000 barrels. By 1861 it had increased to 2,114,000 barrels. Since that date, in response to a growing demand for petroleum products, the annual production of crude oil has shown an almost uninterrupted increase. By the opening of the present century it had reached the annual figure of 63,621,000 barrels. A decade later production had increased more than threefold. By 1920 it had again more than doubled, and with

the passing of another five years production in 1925 reached an aggregate of 755,852,000 barrels.

As the annual output has increased, the geographic areas in which oil has been found have continuously expanded until today oil is produced in nineteen different states. Production comes mainly from seven major oil-producing regions ranking as follows: (1) Mid-Continent, embracing portions of Kansas, Oklahoma, North Central and Western Texas, Northern Louisiana, and Southern Arkansas; (2) California; (3) Rocky Mountain, including portions of Wyoming, Montana, and Colorado; (4) Gulf Coastal, embracing the coast country of Texas and Louisiana; (5) Appalachian, embracing portions of New York, Pennsylvania, Eastern Ohio, West Virginia, Kentucky, Eastern Tennessee, and Northern Alabama; (6) Illinois and Southwest Indiana; and (7) Lima-Indiana, including a portion of Northwestern Ohio and Northeastern Indiana.

The Production of Petroleum. It is a long march from the crude oil as it is found in these several regions in a natural state in underground porous rock to the multiple products found in the hands of a myriad of consumers scattered over the face of the earth. On a basis of the various functions performed along the way, the oil industry may be divided into four major divisions: production, transportation, refining, and marketing.

The production of oil involves the discovery, development, and exploitation of oil-bearing lands. As previously suggested, oil is found underground in porous rocks at depths varying from a few hundred to several thousand feet. Various theories have been advanced by the scientists explanatory of the formation and accumulation of oil in its underground reservoirs. According to the theory now most generally accepted, petroleum, which is a hydrocarbon, has been formed from the organic remains of marine plant and animal life which have been deposited in water-laid or sedimentary rocks along ancient sea-coasts. Subsequent depositions have covered these remains, and under the influence of pressure and heat during a long period of time, a natural distillation process has resulted in the formation of crude petroleum and natural gas. The strata from which oil is now produced were originally deposited horizontally, but while in this position they are incapable of producing oil in commercial quantities. The strata have subsequently been forced into undulations by the wrin-

kling or folding of the earth's crust. Petroleum, set in motion by the gas pressure, has generally migrated from its original source, the direction of migration being upward along the sloping beds of porous rock until further migration has been prevented by an overlying impervious formation or by the downward curvature of the stratum. Oil pools are, therefore, generally convex in shape and resemble an upturned basin, the oil and gas being found under the dome or crest of an impervious layer of rock. Oil and gas are generally associated with water, and the three substances when found together have distributed themselves in the order of their specific gravity, the gas being found in the upper part of the underground fold, the oil next, and the water beneath the oil. Favorable regions for the finding of oil are areas that are underlain by sedimentary rocks, consisting of a source rock, a reservoir rock, and a cap rock, which have been gently or moderately folded without having undergone any considerable degree of metamorphism.

The location of the first oil well was determined by the presence of oil seepages at the earth's surface. Since that time chance has played a leading rôle in the discovery of oil-producing areas. The willingness of speculators to stake their all in a wild-cat search for oil in the hope of striking it rich has accounted for the discovery and development of many new fields. But while in the past the industry has relied upon the gambling proclivities of mankind to insure us an adequate supply of crude oil, the sciences of geology and physics have in recent years done much to eliminate the element of risk in oil-production activities. The geology of oil is the geology of rock structure. By a careful mapping of surface structure it is possible to determine with remarkable accuracy the most probable regions for the accumulation of petroleum. With the beginning of exploitation well-kept drilling records give additional exact data regarding the underground conditions. And these, coupled with the surface measurements, give a remarkably precise and complete picture in three dimensions of the geologic conditions of a particular area. More recently, too, these strictly geological methods have been supplemented by various geophysical devices. Chief among these have been the torsional balance, the seismograph, and the determination of underground temperatures. While it still remains true that the precise location of an oil-producing area can be determined only by means of the drill, the leading oil companies no longer rely upon the purely chance

methods of former days. On the contrary, they have come to depend upon the advice and counsel of a staff of experts trained in the physical sciences. Through the application of modern engineering principles the production of oil has been lifted from the realms of pure chance and made to approach a scientific exactitude.

Once an oil pool has been located, the oil is recovered by boring a hole through the earth's crust until the underlying impervious rock is pierced. Thereupon the oil, actuated by the gas pressure, begins to flow to the earth's surface. Where the oil is abundant and the gas pressure sufficiently great, Nature may deliver the crude product to the earth's surface in prodigious quantities. While some few wells in America have attained an initial daily flush production running into the tens of thousands of barrels, the greater proportion of our annual production comes from a multitude of wells each producing only a few barrels daily. On December 31, 1921, there were 274,500 oil wells in the United States having an average production per well per day of only 4.9 barrels. Most of these wells had ceased to flow naturally, and it had become necessary to install pumps in order that they produce at all. The steady annual increase in crude production has been secured only at the expense of drilling a large number of new wells annually. Thus, 16,523 wells were completed in 1925, at a per well cost varying from a few thousand dollars to several hundred thousand dollars.

To meet the ever expanding demand for petroleum products, not only has the industry engaged in an unremitting endeavor to find and exploit new oil pools, but there has been developed an improved technique to insure a more thorough exploitation of possible producing areas and a more complete extraction of the oil from developed pools. The drilling of an oil well through solid rock to a depth of 69 feet by Colonel Drake in 1859 was viewed as a novel and striking engineering feat. In 1925 a California well was drilled to a depth of 7591 feet, the deepest producing oil well in the world. The striking fact about this well is that it does not represent a freak hole drilled with special equipment at a terrific cost to break a record, but that it represents a normal development in well-drilling technique. The day of the 7500-foot well seems to have definitely arrived. This has been made possible by the development of machinery built to stand the heavy strains imposed. Derricks are larger and stronger than ever before. While wood and steel derricks are at present in about equal favor,

there has recently been a sharp trend toward the steel derrick, and the days of the wooden derrick seem numbered. Radical changes in the drill pipe have likewise been made in the last few years. The newer pipes are heavier in weight and tougher in fiber. New fishing tools and new drilling stems and bits have been made available. The new technique has resulted in the tapping of deeper reservoirs in pools from which production at the upper levels had about ceased. The old Spindle Top pool in the Gulf Coastal field, first discovered in 1901 with oil at a depth of from 700 to 1600 feet, reached a maximum yearly production of 17,421,000 barrels in 1902 and thereafter declined in yearly production to 295,000 barrels by 1922. This pool came back in 1926 with a total production of 13,370,000 barrels, most of the oil coming from newly tapped horizons from 2600 to 5000 feet below the earth's surface.

Similar progress has been made towards a more complete extraction of oil from pools whose production had become negligible. With a decline in gas pressure, oil wells cease to flow naturally and it becomes necessary to install a pumping system. This involves considerable expense and, with a complete disappearance of gas pressure, even this method becomes futile. It is variously estimated that under the methods of production which have prevailed in the past, from 75 to 90 per cent of the total oil has remained underground. This percentage is being lowered in recent exploitation by the use of vacuum pumps, by a controlled system of water flooding, whereby water under pressure is forced into certain strategic wells and thereby made to expel oil from adjoining wells, and by a similar air-pressure system. By means of these various devices it has been possible to reopen fields in which production had ceased and which had temporarily been abandoned. A yet more recent development, still in an incipient stage, is the mining of oil through a shaft sunk from the surface to the oil-producing horizon.

It is only by means of these various devices that our annual production has been able to register an almost uninterrupted increase, and to the new technique is to be accredited in part the responsibility for the overproduction splurge which has characterized the industry for the past seven years.

The Transportation of Petroleum. The petroleum industry, confronted with the problem of moving a bulky, liquid raw ma-

terial, has developed a system of transportation along individual lines which functions almost entirely independently of the usual transportation agencies. The system consists in the main of a network of pipe lines connecting the various producing areas, frequently in remote regions, with the oil refineries, which tend to be located near population centers. Supplementary to the pipe lines, a tank steamer has been especially designed for coastwise and ocean traffic and a tank car for railway and motor traffic. A pipe line, as the term is customarily used, consists not only of a line of pipe but of the whole plant which is used to transport oil from one point to another, including initial, intermediate, and terminal tankage facilities, power plants, a system of communication between stations, and all other equipment necessary for the safe and expeditious conveyance of oil. The system includes main or trunk lines extending from the oil fields to the refining centers and numerous feeder or gathering lines for conveying the oil from the individual wells to the trunk lines, together with the necessary storage facilities both at the point of departure and at the point of destination.

The pipes for conveying the oil are made of steel and are laid about 18 inches underground. Trunk lines vary from 8 inches to 16 inches in diameter, while gathering lines vary from 2 inches to 8 inches in diameter.

The crude liquid is forced through the pipes by means of pumps operated by internal-combustion or steam engines. The distance between pumping stations varies with the topography of the country, the character of the crude oil, the quantity to be shipped, climatic conditions, and numerous other factors which may affect the mobility of the product. The average distance between stations in the Mid-Continent field is about forty miles.

In order to report leaks and to dispatch oil shipments, instant communication between pumping stations must be maintained. In response to this need, the oil companies have constructed and maintain telegraph or telephone systems paralleling their pipe lines, available for use at all times. By means of this unique and efficient transportation system, oil may be dispatched from a producing well on a Central Texas farm, conveyed along its underground journey, and delivered to a refinery on New York harbor without having been touched by the hand of man.

According to figures recently released by the Bureau of Mines,

there was a total of slightly more than 90,000 miles of pipe lines in the United States on May 1, 1926. This total mileage was about evenly distributed between trunk lines and gathering lines. On the same date the grand total of tankage (exclusive of producers' storage at the wells) for the storage of crude petroleum and petroleum products at the refineries amounted to over 800,000,000 barrels, 90 per cent of which were of steel construction.

As the foregoing facts have indicated, the business of pipe-line transportation is essentially a large-scale undertaking, necessitating a large fixed investment and catering to large and secure financial organization. The cost of pipe-line construction varies with numerous factors, chief among which is the distance between pumping stations. The investment required for a single 8-inch line from the Cushing, Oklahoma, pool to New York harbor would be approximately $20,000,000. From an economic and financial point of view, the operation of pipe lines is quite similar to railway transportation. Pipe-line transportation, like railway transportation, necessitates a large fixed investment and is subject to the principle of decreasing cost up to full utilization of plant and equipment. A large proportion of both construction and operating expenses constitutes fixed charges regardless of the business done. Expenses incidental to the purchase of right-of-way, surveying, construction of line communication, etc., vary little if at all with the size of the plant. Likewise, much of the operating expense varies little with the volume of traffic. Expenses for labor, superintendence, ground-rent, depreciation, etc., remain about the same whether the plant is operated at full or partial capacity. Should an increase in the volume of traffic of a particular line eventually necessitate an enlargement of capacity, existing pumping facilities, right-of-way, etc., may be utilized for the construction of parallel lines, the additional traffic being thereafter handled under the principle of diminishing cost. This reasoning is substantiated by cost data presented by the Federal Trade Commission covering the major lines of the country, which establish the fact that the most efficient lines of the country are those operating on the largest scale. The peculiar nature of the industry accounts for the fact that the pipe-line transportation systems of the country are under the control of a few relatively large concerns.

The Refining of Petroleum. The petroleum transportation system delivers its liquid cargo directly to the refineries of the

country wherein the fabrication of the petroleum products takes place. The manufacture of petroleum products is a distillation process. As previously stated, petroleum is a hydrocarbon. There is no essential difference in its various products aside from that of volatility, and the lines of demarcation between them are not distinct and clear cut. By the application of heat the successive components are vaporized and separately led to a condensing plant. The refining process is a joint process. As heat is applied, the lighter components are the first to be given up, and when condensed, yield what is commercially known as gasoline. At a somewhat higher temperature the less volatile fractions vaporize and, upon condensation, yield kerosene. The undistilled residue may be used as it remains as gas oil or fuel oil for fuel purposes, or it may be put through a more complete refining process and made to yield in addition to fuel oil a residue of lubricants together with other products.

The basic principles of refining have undergone no fundamental change since the advent of the petroleum industry. The extent to which the principles have been applied, however, has shown a tendency to adapt itself to the changing character of the demand for petroleum products and to the relative abundance of the crude oil.

Petroleum refineries may be divided roughly into three major classes or types: skimming or topping plants, complete refineries of the straight-run type, and complete refineries utilizing the "cracking" process in pressure stills. Skimming or topping plants, as the name signifies, do not carry the distillation process to completion. They are content with merely "skimming" or "topping" the crude petroleum of its lighter constituents, gasoline and kerosene, and with disposing of the residuum in its semi-crude state for fuel purposes. The complete refineries of the straight-run type carry the process a stage further and recover from the semi-crude product its content of lubricants, together with by-products. Such refineries recover the major products with a minimum of chemical change in the refining process. They lack the ability to secure from the crude petroleum more gasoline than it naturally contains. Complete refineries utilizing the so-called "cracking" process likewise turn out the four major petroleum products, gasoline, kerosene, lubricants, and fuel oil, but the process yields a greater percentage of gasoline than the crude oil

will yield under ordinary distillation. By conducting the distillation process in stills under high pressure, the heavier molecules of petroleum are broken down to yield lighter molecules, which upon condensation form commercial gasoline. Such pressure stills may utilize as their raw material either kerosene, the fuel oil residue from complete refineries, or the heavier crude oil. This process, as at present developed, has the capacity to produce by volume more than twice the amount of gasoline that may be secured by ordinary distillation.

Refining practice has shown a tendency to pass through these three evolutionary stages as there has been a shift in the nature of the demand for petroleum products and as the supply of petroleum has become less abundant in particular areas. In the early decades of the petroleum industry it was the demand for kerosene as an illuminant which furnished the impetus for petroleum production. Prior to the middle of the nineteenth century society was dependent primarily upon the whale fisheries and the tallow-candle industry for the source of its illumination. With the production of petroleum in commercial quantities, kerosene very quickly supplanted these older illuminants. It pushed its way into the uttermost parts of the earth, where it served to lighten the darker corners of civilization. With kerosene as the major petroleum product, refineries of the topping or skimming variety came into great vogue. As mineral oil for lubricants came to play a more important rôle in our industrial life, the skimming plant gave way to the complete refinery. With the more recent widespread use of the motor car, gasoline has become the stress product in the refining of petroleum, and the pressure still threatens to supersede the straight-run refinery as the dominant type. A recapitulation of this same development may be seen in the life history of individual oil fields. With the crude supply locally abundant during the period of flush production, the skimming plant appears. As the supply of crude wanes, it becomes financially expedient to extract a more complete range of values from the crude oil, and the skimming plant makes way for the complete refinery. Later, with increasing stress and settled output, the development is in the direction of the pressure still, which carries the extraction of values still further by the conversion of a low-value product into one of greater worth.

The changes in the nature of the refining practices for the indus-

try at large corresponding to changes in the demand for refined products are summarily indicated by quantitative data on refinery output. In 1899 kerosene represented by volume 57.7 per cent of the crude oil run to the stills; lubricants represented 7.7 per cent; and gasoline represented 12.8 per cent. By 1904 the volume of kerosene by percentage of total crude run to the stills had declined to 48.2 per cent, while the percentage of lubricants had increased to 11.2 per cent. This change is indicative of a more widespread resort to the complete type of refinery. An increase in crude-oil production was still able to take care of the increase in consumption of gasoline, and gasoline at this date represented by volume only 10.3 per cent of the total crude run to the stills. Since 1904 the increase in crude production has been more than adequate to take care of the increased consumption of mineral-oil lubricants, and by 1923 the percentage which these represented of the total crude run to the stills had declined to 4.4 per cent. Gasoline, however, has continuously drawn more heavily upon that portion of the crude which previously had gone to the making of kerosene or fuel oil. In 1923 kerosene represented by volume only 9.4 per cent of the total crude run to the stills, while the percentage represented by gasoline had increased to 30.9 per cent. This increase in the quantitative importance of gasoline is not to be explained entirely by the advent of the cracking process, although it is in part a reflection of this development. It is likewise in part due to a change in the character of gasoline under the straight-run type of distillation. Gasoline is not a distinct chemical product of definite qualities. It consists of a series of hydrocarbons ranging from small, light molecules to heavier molecules. By carrying distillation further under the straight-run process, more gasoline of heavier, and hence poorer, character has been secured. Prior to the coming of the automobile, in the days of kerosene's supremacy, gasoline was a waste product. The temptation to mix it with, or call it, kerosene for sales purposes was great. Hence, the appearance of state kerosene inspectors as a measure of protection to prevent explosion of the household oil lamp. Today the situation has been reversed and the temptation has been to increase the supply of gasoline by drawing more heavily upon the kerosene constituents of the crude oil. This has been achieved in part by carrying the distillation process further in the straight-run refinery and in part by the more widespread use of cracking.

The importance of this latter factor may be indicated by a brief historical résumé of the development of the cracking process. The first patent covering the cracking process was issued to Dr. W. M. Burton of the Standard Oil Company of Indiana in 1913. In 1918 approximately one tenth of the total gasoline output of the country was produced in pressure stills. By 1925 this percentage had increased to about 25 per cent, and in 1926 it was estimated to be about 33 per cent.

While the recent years have witnessed a tendency for the more complete type of refinery to supplant the less complete, the industry still makes use of all of the three major types described above.

The Marketing of Petroleum Products. For the distribution of petroleum products an efficient marketing system (as judged from an individual business point of view) has been developed. Gasoline, the more valuable product, is loaded at the refinery into tank cars, or into tank steamers where the refinery is located adjacent to a water highway, and is shipped by rail or boat to storage stations located at strategic marketing centers. From these storage stations it is delivered by tank truck or wagon to retail filling stations, garages, or any consumer who purchases in wholesale quantities. In recent years great effort has been exerted by the marketing agencies to locate retail filling stations at strategic traffic centers, and considerable use has been made of automobile registrations and road traffic figures as indices for the location of stations.

Since kerosene is consumed primarily for domestic household uses, the filling station has played an inconspicuous part in its distribution. Most kerosene is delivered directly to the consumer by means of tank wagons, or is dispensed over the counters of the local grocery stores.

Fuel oil is consumed mainly in bulk by large industrial establishments, railroads, and steamships; the machinery for its distribution is relatively simple. It is sold for the most part on direct consignment from the refinery to the consumer.

The sale of lubricating oils involves still another type of marketing machinery. Correct lubrication is a highly important engineering problem. Its solution has called into being a vast variety of lubricating products designed to meet individual mechanical needs. A considerable volume of lubricants is dispensed through the retail filling station and local garage to meet the demands of automobile users. Because of the technical problem

of correct lubrication, sales in industry generally involve the services of a lubricating engineer familiar with the mechanical advantages of particular lubricants. Such sales frequently are made through the intervention in the marketing chain of a jobber who may have compounded a special product for sale under a special trade name. Competition among refiners and jobbers has resulted in a confusing multiplicity of brands in the sale of which advertising has come to play an important rôle.

Financial Control of the Petroleum Industry. Such, in brief, is the present-day organization of the oil industry on a basis of function. Financial control, however, does not coincide with the functional organization. On the contrary, the four divisions of the industry are largely under the control of a relatively few, highly integrated companies which either directly or through their subsidiaries engage in all the different branches of the industry from the production of crude oil to the marketing of the refined product. Prior to 1911 the Standard Oil Company of New Jersey, a holding company, enjoyed virtually a monopoly control over the various divisions of the industry. For purposes of industrial and financial efficiency, the constituent companies of the New Jersey corporation specialized almost exclusively in a single branch of the industry. For example, the South Penn Oil Company was engaged exclusively in the production and purchase of crude petroleum. The New York Transit Company was engaged primarily in the pipe-line transportation of crude petroleum. The Standard Oil Company of Kansas was engaged exclusively in the refining of petroleum, and the Continental Oil Company was primarily a marketer of petroleum products. Some of the larger companies, as for example the Standard Oil Company of New York, engaged in both the refining and marketing branches of the industry; but there was a notable tendency towards industrial specialization on the part of the individual companies within the Standard group. The New Jersey Corporation as a financial and economic entity, however, was a highly integrated concern, engaging directly or through its subsidiaries in all the industrial processes from the production of crude oil to the marketing of the highly fabricated products. A constituent company acted as a link in the chain of processes from the raw material to the finished commodities.

In 1911, by a decree of the Supreme Court of the United States, thirty-three of the major constituent companies owned by the

Standard Oil Company of New Jersey were separated from the financial control of the parent organization. Since that date these companies have operated in financial independence, though some of them have continued to serve, as they did prior to the dissolution, as economic units linking the various Standard Companies into an integrated whole. There has been a tendency, however, on the part of the more important companies to secure independent control over the various branches of the industry. In some instances, integration has been achieved by reaching backward to control the initial industrial activities, and in other cases it has involved a reaching forward to control refining and marketing.

The companies comprising the Standard Oil group today handle about one half of the total traffic in petroleum products. The balance of the business is in the hands of the so-called Independents, consisting of a few large companies and a much larger number of smaller concerns. The larger independent companies have followed the pattern set by the old Standard Oil Company, and are, in the main, highly integrated concerns engaging in all the industrial processes from the production of crude oil to the marketing of refined products.

Such, in brief, is the financial organization and control of the industry at the present time. The industry in 1925 embraced 300,000 producing oil wells, 90,000 miles of pipe lines, 142,000 tank cars, 400 tank steamships, and 500 refineries. The total investment in producing wells, transportation facilities, and refining and marketing equipment exceeded $9,500,000,000.

Labor Conditions. The production, transportation, and refining of petroleum are essentially capitalistic enterprises in which labor plays a relatively unimportant rôle. Engaged in these three branches of the industry, however, there were approximately 302,600 workers in 1920. Approximately 141,000 of these were engaged in the production of oil. The location of oil bears no definite relationship to the existence of urban centers, and frequently discoveries have been made in remote rural areas. Immediately waste land has been transformed into mushroom towns, and villages have become cities overnight. The rapid concentration of population has generally made for a breakdown of law and order; existing institutions have proven inadequate to the task with which they have been confronted, and the result has been general social confusion. In their early life, oil fields are com-

monly characterized by lawlessness, filth, and crime. The rapid expansion of the industry, its speculative and decentralized nature, and its shifting centers of production have made for the appearance of a migratory class of laborers seeking employment in boom fields where the opportunities for high wages seem most apparent. These same factors have made difficult the task of permanent organization. An International Brotherhood of Oil and Gas Field Workers was chartered by the American Federation of Labor in 1900. It remained in affiliation until 1905, with a diminishing membership, however, and in 1906 it disbanded. In 1919 the present organization — The International Oil Field, Gas Well, and Refinery Workers of America — was chartered by the Federation with a membership of 4500. During the next year its membership increased to 20,900 and by 1921 it claimed 24,800 members. Its prosperity was short-lived, however, and since 1921 its membership has shown a continuous decline until by 1926 it claimed only 700 members. While the organized efforts of the workers have accomplished but little in the improvement of living and working conditions, in recent years the larger oil companies have come to appreciate the economic disadvantages of high labor turnover and, in an effort to solve this problem, they have done much to improve living conditions in oil-field regions. Model camps have been established in many communities with ample recreational and educational facilities, and in a few instances employee representation has been established for collective bargaining and the settlement of disputes. Hours of labor are long. In 1920, four per cent of the workers were on a twelve-hour basis,[1] twelve per cent worked ten hours or longer, and fifty per cent worked nine hours or longer daily. Wages, of course, have varied with general business conditions and with the character of the task. In November, 1920, unskilled labor, which comprised the largest single grouping, was paid an average of 58 cents per hour, while the most highly skilled tasks were paid an average of about $1.14 per hour.

In the transportation branch of the industry there were approximately 39,300 workers in 1920. An estimated 75 per cent of these worked nine hours or longer per day, and the average hourly wage varied from 52.8 cents in the case of the unskilled workers, which

[1] Since 1920 the eight-hour shift has been substituted in some localities for the twelve, and the eight-hour day has become the standard in a number of fields.

comprised the largest single grouping, to 84.2 cents in the case of the highly skilled.

Refineries tend to be located more generally in population centers and here living conditions are much better. Of the 122,300 refinery workers it is estimated that in 1920 approximately 50 per cent worked the eight-hour day. Wages varied from 52 cents per hour to $1.11, the modal wage being 57.5 cents. The refinery workers have been no more successful in their endeavor to organize than have the field workers. More generally, however, the employers have taken the initiative in the establishment of company unions and there are a number of companies which today have what are ostensibly satisfactory systems of employee representation in vogue.

Altogether, working conditions seem to have shown considerable improvement in recent years, but uncontrolled production has made for recurring confusion in the industry and just now the oil-field workers are suffering under unemployment and lower wages. The permanent improvement of the workers' lot in so far as the production branch of the industry is concerned seems definitely linked up with the problem of controlled production.

The Problem of Monopoly. Any discussion of the oil industry in America which failed to take account of the problems of monopolistic and competitive control of the industry would be inadequate. It is to a consideration of these broader social aspects of the industry that we now turn.

Petroleum as a commercial enterprise in America made its appearance in 1859. Because of the peculiar nature and occurrence of petroleum, the opportunity for speculative gains in the industry has always been excellent. Oil production offers the same lure as does the search for gold. Its speculative nature with large gains where a rich strike is made, coupled with the migratory character of the mineral, accounts for the continuous flood of oil which has found its way into the American market. There has been an ever-present tendency towards over-production in the oil industry. The result has been recurring periods of price demoralization. The first oil produced in America yielded $20 per barrel. By December, 1861, so plentiful had the product become that the price had declined to ten cents per barrel. By the close of the decade, oil was again selling for $7 per barrel. Such price instability made for financial insecurity and placed a business reward upon price stabilization and control.

The excessive competition in the production of petroleum was communicated to and manifested in the refining and marketing of petroleum products. Refineries sprang up like mushrooms overnight. By 1872 the refinery capacity of the country was estimated to be about three times as great as the total production of crude petroleum at that time. Similar excess of capacity tended continuously to characterize the industry during its early history. The result was keen competition in the purchase of available crude with an upward tendency in the price of the raw product, interrupted temporarily, as previously indicated, by serious price declines. Competition in the sale of the refined products, together with improvements in the refining technique with consequent lower costs, made for low prices of refined products with a corresponding tendency for profits to disappear. Theoretically, such a situation would in the long run have made for the disappearance of the less efficient refiners. Immediately, it made for fluctuating loss and profit, depending upon the demand-and-supply situation at any particular time.

Combination and centralized control under such an economic situation awaited but the appearance of requisite business acumen and organizing ability. Mr. John D. Rockefeller, together with his business associates, afforded these necessary characteristics. Mr. Rockefeller in 1862 was associated with Mr. Clark in the produce commission business. In that year they together backed Samuel Andrews, said to have been a mechanical genius, in a small refinery enterprise in the city of Cleveland, Ohio. From this small beginning the Rockefeller interests, despite the disorganized condition of the industry, continuously expanded the scope of their activities until by 1879, through the instrumentality of the Standard Oil Company of Ohio, representing the corporate control of the Rockefeller properties, or directly by individual ownership, they had secured virtually a dominating position in the transportation, refining, and marketing of petroleum products. In that year the first Standard Oil Trust agreement was executed. In 1882 a new agreement embodying substantially the same principles as the agreement of 1879 superseded the earlier agreement. Under the terms of these agreements control of the numerous properties, owned in whole or in part by Mr. Rockefeller and his associates through ownership of stock in various ostensibly competing companies, was centralized under a board of trustees consisting of nine

members. Between 1879 and 1911 the form of this control underwent several changes, but the fact of control remained unmodified.

The highly competitive situation which existed in the petroleum industry prior to the ascendancy of Standard Oil made the formation of combination and monopoly peculiarly attractive. Combination, furthermore, made possible certain economies in the organization and operation of the industry. Nevertheless, it should be observed that the methods pursued by the Standard in securing and maintaining its monopolistic position were not always reflective of superior efficiency. On the contrary, the organization seems to have indulged frequently in business practices which have since come to be regarded both in law and economics as unfair and predatory. The methods pursued in securing its dominating position extended over a wide scale — from the relatively innocuous practice of purchasing companies secretly and operating them as ostensibly competing independent concerns through the securing of preferential treatment and rebates at the hands of the common carriers of the country, local price cutting, the maintenance of a spy system on its competitors' operations, to armed opposition in its fight against competitors. Through its unremitting and relentless efforts the Standard Oil Company was able to secure and maintain virtually a monopoly in the oil industry. During the decade prior to the dissolution of the Standard Oil Company in 1911, the organization controlled well over 80 per cent of the business in the transportation, refining, and marketing of petroleum and its products.

Space will not permit a detailed discussion of the effects of this monopoly control upon American consumers of petroleum products or upon the oil industry. Some economies unquestionably were introduced, and the industry somewhat stabilized. There is also evidence to indicate that the Standard exercised the business advantage of its monopoly position to enhance its profits at the expense both of the consumers of petroleum products and the producers of crude oil.

As a result of the findings of the Bureau of Corporations after an extensive investigation of the activities and position of the Standard Oil Company of New Jersey, the holding company under which the control of the ubiquitous Standard properties had been concentrated in 1898, the Company was prosecuted by the Federal government on the grounds that it was a combination and monop-

oly operating in violation of the Sherman Anti-Trust Act of 1890. A final decision was handed down by the Supreme Court of the United States in May, 1911, ordering the Standard to dissolve itself in accordance with a plan formulated by the Court. While the Standard Oil Company controlled 114 companies at the time the decision was rendered, the dissolution decree ran against only thirty-three of the companies. In accordance with the decree, direct control of the thirty-three companies concerned was severed from the parent body. The stock of these companies was distributed among the former stockholders in the parent organization on a basis of the amount of stock held by each in the parent body. The immediate effect of this change was a decentralization in control, but no change in ownership.

Effect of the Dissolution Decree on the Competitive Situation. As previously stated, prior to the dissolution of the Standard Oil Company, the numerous constituents of the company had become highly specialized concerns engaging in the main in but one branch of the industry. There had likewise been a geographic narrowing in the scope of the operations of particular companies. For example, the entire United States had been divided for purposes of marketing efficiency into eleven marketing districts, in each of which a single Standard company functioned. Because of this geographic and functional specialization, the Standard companies in the aggregate were characterized by a high degree of economic interdependence. The production and purchasing companies passed the crude product on to the transportation agencies; the transportation agencies turned the product over to the refining companies; and these, in turn, disposed of the refined product either to a specialized marketing company or to a marketing division of their own organization. The dissolution decree did not disturb this economic equilibrium. The various companies continued to function in the same manner and in the same territory as before the decree. Immediately it did not, therefore, establish competition in the industry. Some one Standard company continued to dominate the particular branch of the industry in which it functioned in a particular geographic area. Price control seems not to have been immediately affected.

With the march of time an expansion in the industry has taken place, together with a shift in the geographic areas in which production activities have been carried on. Meanwhile the predatory

business practices previously pursued by the Standard companies have been discontinued. The situation has beckoned new capital into the industry, and the period since 1911 has witnessed a marked increase in the financial and industrial importance of independent companies. Today it is estimated that members of the old Standard group in the aggregate handle only about 50 per cent of the total traffic in petroleum and its products. The situation, in short, has become a more nearly competitive one.

Likewise there has been a lessening in the economic dependence of the various Standard companies upon other members of the group. Fear of a petroleum shortage in the near future has led the more independent and aggressive refining and marketing concerns to integrate backward and thereby secure direct control over the raw product. This has worked to the disadvantage of the specialized production and transportation companies, and these have countered with an integration program extending forward, that they might control their own market. In brief, there are evidences of the breakdown of the old Standard monopoly in the face of economic developments — a breakdown which legal enactment alone seems to have been unable to attain. Thus far, however, competition has resulted primarily in a competition of service rather than a competition of price. There are evidences that certain Standard units still dominate in certain limited geographic areas, although in general the severity of competition has very greatly increased during the past decade. What the outcome will be remains to be seen.

Competition and the Problem of Waste. The increasing severity of competition serves to focus attention upon the question of the desirability of competition as a regulatory force in the oil industry. In this regard it should be noted that the production of petroleum has remained since the advent of the industry a highly competitive enterprise. Under our system of private ownership, title to minerals under the surface of the earth is vested in the owner of the surface rights. Private property in land, with small holdings the rule, coupled with the hazards and uncertainties of oil-finding, have made a monopoly in oil production difficult. The maximum percentage of total production directly controlled by the Standard was reached in 1898, at which time the Standard produced approximately 33 per cent of the annual yield. By 1906 this control had shrunk to 11 per cent. The Standard's previously dominating

position in the industry rested upon its control of the transportation, refining, and marketing of petroleum and its products. As chief purchaser, and in many localities exclusive purchaser of crude oil, its control over price was effective.

The production of petroleum, on the other hand, has been relatively a small-scale affair with the unit of operation the private property tract. Property lines obviously have no bearing upon the geological conditions under which oil is found. As previously explained, oil is found underground in proximity to gas and water, the three substances having distributed themselves in the pores or voids of the underground rocks in the order of their specific gravity. Gas will be found in the uppermost part of the underground fold; oil will be found under the gas; and water beneath the oil. The underground gas and oil are in intimate association with each other. Where the gas is present in large volume, some of the more volatile constituents of the crude oil may be found as vapor suspended in the free gas. Where the gas is smaller in volume or under great pressure, much of it may be found in solution in the oil. Prior to the disturbance by the drill, the three substances have established themselves in a delicate condition of equilibrium, stable only so long as the underground reservoir remains untapped. When the restraining stratum is punctured by the drill, the expansion of the accompanying gas drives the oil to the surface or entices it thereto as it makes its own hasty exit.

To secure at the lowest possible cost a maximum recovery of oil from its underground reservoir, where it lies hidden in intimate and delicate association with both water and gas, presents an engineering problem intriguing in its complexity and challenging in its potentialities. If drilled wells which furnish a channel for the escaping oil and gas as they make their way to the earth's surface are properly located and spaced, the gas and in many instances the water, too, may be made allies in the capture of the elusive oil. In truth, the amount of oil recovered depends in the main upon the location of and the distance between wells and upon a proper synchronization of the drilling program. The proper location and spacing of wells involves a careful study of the surface geological conditions supplemented by mechanical tests of gravitational factors, and, as the drilling program proceeds, by well-kept drilling records.

Under any system of exploitation it would be impossible to make a complete extraction of the underground petroleum. In the

light of the highly intricate engineering problems involved, the program of exploitation which offers greatest promise of success takes as its unit of operation the geological unit — the oil pool. In actual practice, however, under our competitive system of private property, the unit of exploitation has been the property tract. The number and location of wells have been determined by the run of property lines on the surface; the larger the tract, the fewer the wells; the smaller the tract, the greater the number of wells.

Oil is a migratory mineral. Actuated by the gas pressure, it will readily travel for considerable distances underground. Since oil is migratory, it is essentially no man's oil until it reaches the surface. It then belongs to the individual through whose well it has issued. The arbitrary division of a geological unit — the underground pool — into multiple tracts corresponding to property units, as a basis for mining a migratory mineral, has resulted in the production of oil on a principle of robbery. Wells customarily follow property lines with little regard to underlying geological conditions, the aim being to extract as much of the oil from under a neighbor's tract as possible or to prevent a neighbor from extracting the oil from under the adjoining property. Once a pool has been discovered, there is a premium on rapid exploitation, since the early wells secure the advantage of maximum gas pressure and therefore produce more heavily than later wells. The result has been a mad rush for oil, the confusion and waste attendant upon which are difficult to picture adequately.

Because of their anxiety to secure their share and more of the underground mineral, producers have drilled more wells than have been necessary to secure the recoverable oil. Excessive duplication and overdevelopment have unquestionably resulted in a very much greater expense in securing the oil than would have been necessary under some system of unified operation and control which overlooks the factor of property lines and takes as its point of departure the geological unit in which oil is found. Likewise, much gas, valuable both as a fuel and as an energy resource, has been permitted to escape unused into the atmosphere because the wild and uncontrolled scramble for oil did not permit its utilization. It has been estimated that in the Cushing field in Oklahoma at one period there was an average daily waste of 300,000,000 cubic feet of natural gas, or more than 100,000,000,000 cubic feet of natural gas in the course of a year, the fuel equivalent of

5,500,000 tons of coal. What is of even greater importance is the fact that much of this gas, because of an improper spacing of wells and an uncoördinated drilling program, escaped without having been made to do its quota of work in delivering oil to the surface. The result was a large loss of oil through incomplete recovery. Likewise, the property-owning basis of exploitation, because it necessitates or facilitates an uncoördinated drilling program, is responsible for large losses of oil due to an incomplete recovery occasioned by the encroachment of underground water which in many instances drowns wells and even complete pools. And finally, unrestricted competition, which makes control of production impossible, has made for recurring periods of overproduction with accompanying financial loss and even bankruptcy. Witness the present demoralized condition of the industry with only breakers ahead.

These wastes are to be laid directly to the application of the competitive system in mining a migratory mineral which recognizes no property lines and transgresses the principles of ownership. They result directly from a maladjustment between the geology of oil and the economics of its exploitation. In brief, unrestricted competition in the mining of oil has made for tremendous wastes, the precise extent of which cannot be calculated.

Competition, to the extent that it has existed in the other branches of the industry, has made in certain respects (whatever its advantages may have been) for a loss of efficiency and economy. The pipe-line transportation of petroleum, because of its large-scale characteristics with large fixed charges and a tendency to decreasing cost up to full utilization of plants and equipment, is a natural monopoly. Unnecessary duplication of pipe lines following the same route and serving the same areas has unquestionably resulted in higher costs. The over-rapid production of petroleum, the result of excessive competition, has tended to delay the application of the cracking process in the refining of petroleum. The result has been that much of our oil, containing a high gasoline content which might have been more completely extracted, has been utilized for fuel purposes. And finally, the strenuous drive for business through the retail gasoline filling station, which has developed with the decline in the power of the Standard, has resulted in a needless duplication of filling stations to meet the needs of automobile users.

Conclusion. It is impossible here to give adequate consideration to certain controversial questions which have been raised in the course of this account of the American oil industry. If the discussion has centered the readers' attention and thought on the important question of the social control of business, the author's purpose has been well served. The oil industry has been under the control of business enterprise actuated by the profit motive. Under this control, individual initiative has resulted in a phenomenal development in the industry, and the myriads of car users and other consumers of petroleum products find at the present time a ready abundance of the petroleum commodities upon which they have unconsciously come to depend. There is, however, a widespread belief at the present time that oil production in America is destined in the near future to undergo a decline. The Federal Oil Conservation Board appointed by President Coolidge in December, 1924, in its report made public in 1926, expressed the belief that our proven petroleum reserves are adequate only for a period of six years. New fields may be discovered and thereby make this calculation of little importance; and even though our own production should rapidly decline, there are vast untapped resources outside the boundaries of the United States. In this regard it should be observed that the oil industry has been distinctly an American enterprise. America has produced more than 64 per cent of the total world production and currently consumes an even larger percentage of the annual world output. The extent of the foreign reserves is not known, however, and their exploitation raises serious questions in the field of political relations. The problem of the conservation of our remaining resources is therefore an important one. In this regard, and by way of conclusion, it should be pointed out that the problem is in considerable part a result of the notions which we have in our heads. We have insisted upon unrestricted competition as an effective regulator of industrial processes. Economical oil exploitation, however, can be secured only by a modification of competitive practices and the substitution of some form of unified control. That involves the difficult task of a change of mind. It calls for the exceedingly unpleasant process of thought taking. It is difficult to think until a problem is appreciated and a crisis is faced. Today we have plenty of oil.

CHAPTER XVII

THE HISTORY OF RAILWAY EQUIPMENT

By William H. Woodin[1]

On March 1, 1927, a company of men from all parts of the United States gathered in Baltimore, Maryland, to celebrate the 100th Anniversary of the corporate life of the Baltimore and Ohio Railroad. That was the name given to a vision, for it was not until a full quarter of a century had elapsed from the time when the "cornerstone" of the B. & O. was laid by a last surviving signer of the Declaration of Independence that the tracks of this, the oldest railroad in the world still operating under its original charter, reached the eastern bank of the Ohio River.

Thus was the far-sighted vision embodied in its name fulfilled. Thus, after a hundred years of railroad progress, one of the greatest of all the romances of American industry, we may definitely fix — out of the chaos of conflicting claims — the credit for the beginnings of American railroad-building, and therefore of the beginnings of construction of railway equipment.

A striking example of the eternal workings of the law of supply and demand is furnished by the history of the birth and growth of the railroad-equipment business. It is, of course, a truism to declare that there could be no railway-equipment business before there were railways; yet, long before steam locomotion had come into being, the solution of problems of land transportation had brought into existence not only rails and mechanical carriages, but other devices which, when steam locomotion became an accomplished fact, were re-adapted for the new uses.

Evolutionary Growth of Railroads. The whole thing was an evolutionary growth. It was on the backs of women that the first burdens were carried along trails, and when these burdens were transferred to the backs of animals, a great step in advance

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had been made in our civilization. Undoubtedly, the first mechanical carriage which took the burden off the beast's back was a rough-hewn plank drawn along the road by an animal. This plank was soon transferred into a sledge; it was not long until this rude cart became equipped with rowlets — the first rude wheels the use of which demanded that the old foot-trails be converted into roads. It was not until the seventeenth century that some mechanical genius in England devised the plan of laying wooden rails along the road so that coal from the English collieries might be more easily transported. This was the actual beginning of the railroads.

The first cars used on these wooden rail colliery roads were bulky carts made with four rowlets fitting the wooden rails, and they were, in effect, nothing more than boxes mounted upon rollers. Each had a capacity of about one ton of coal, and they were either horse-drawn or propelled by gravity. For a long time the use of these first "freight cars" was confined to the hauling of coal, but the first successful application of steam for motive power, which occurred during the second decade of the nineteenth century, saw the emancipation of railroads from their dependence on animal power or gravity, and furnished the impulse for the growth and development of the railway systems of the world.

The beginnings of the history of railroad equipment in America must be searched for in some period prior to the incorporation of the Baltimore and Ohio Railroad, the first organized railroad in America. The act of its incorporation was passed by the Maryland Legislature in 1827.

Chesapeake and Ohio Canal. Up to that period in the history of our country, the tides of immigration and trade had been held back on the Eastern Seaboard by the physical fact of the barrier of the Allegheny Mountains, and it was not until 1825 when a way around this natural bar was found, by way of the Erie Canal and the Lakes, that the congested tide began to move slowly forward.

The tremendous trade advantages that the openings of these waterways gave to New York threatened at once the commercial supremacy of Baltimore and Philadelphia, and it was natural that these cities, seeking to hold their advantage, should try to make one of George Washington's dreams come into actual being by hastening the building of the Chesapeake and Ohio Canal. But there were almost insuperable objections to the construction of such a canal. Engineers reported that along its 241 miles of

length such a canal would have ascent and descent aggregating 3125 feet and that to overcome these, 398 locks would be required. The total cost was estimated at $22,375,427; and it was shown that when the canal was built — if this were possible — the water supply which would have to be drawn from the mountain streams would be uncertain. Yet even in the face of these difficulties of trying to rival New York's coming supremacy, no one seemed to have an alternative to offer.

It was from England that the first practical suggestion came. A letter from Evan Thomas to his brother, Philip E. Thomas, a Quaker merchant and philanthropist and one of the most highly esteemed citizens of Baltimore, conveyed the news of an English plan to build a railroad from Liverpool to Manchester over which carriages would be drawn upon iron rails. The letter said: "Some say this will afford a cheaper and a quicker way of hauling goods than even a canal." The result of this letter was that twenty-five of the most influential men in Baltimore, including Charles Carroll, of Carrollton, one of the signers of the Declaration of Independence, met on the evening of February 12, 1827, to discuss the feasibility of a railroad from Baltimore to the West. At that time, there was no such thing as a railroad for transporting passengers and merchandise between distant points.

There were, it is true, at this early period, a few so-called railroads in England: crude and inadequate affairs for moving coal from the mines to the nearest available water transportation.

First American Railroads. The first railway in America was built by Gridley Bryant. It ran from the granite quarries near Quincy, Mass., to tidewater on the Neponset River, a distance of three miles. It was used solely to haul granite from the quarry to a point from which it could be conveyed by water to Boston. The granite for the Bunker Hill monument was transported over this first railroad. The gauge was five feet. The rails were pine timbers, six by twelve inches, on top of which was an oak scantling two by four inches, faced with bar iron five-sixteenth of an inch thick and two and a half inches wide. The ties were of stone, twelve inches square and eight feet long, laid on a foundation of broken stone three feet deep. Such a substantial construction was expensive, costing $11,250 a mile, but it reduced the cost of transportation to one sixth of what it had been. This road was never operated except by horses and carried no traffic but stone.

The second railroad in America was the Mauch Chunk Railroad, extending from the Lehigh River to the Summit Mines near Carbondale, nine miles distant, at an elevation of 936 feet from the river. The entire nine miles were built in two months and three days at a cost of $27,000. On the Mauch Chunk Railroad each of the cars had a dead weight of 1600 pounds and a carrying capacity of 3200 pounds, the ratio of dead-weight carrying capacity being figured as 1 to 2.

Of course it must be understood that for these, the first railroads in America, there had been as yet absolutely no thought of the steam locomotive — the motive force. The first "brigade" (as they called it) of cars was pulled by one mule, and at the first public demonstration of the prodigies that could be performed by this wonderful new railroad an exhibition "brigade" of eight cars was loaded with 200 barrels, or thirty tons of flour, and one horse drew this a distance of six and one half miles in forty-six minutes.

First American Locomotive. A suspicion that these horse-drawn cars would never be the success that had been anticipated caused constant search for new forces of motive power. Evan Thomas, brother of the president, rigged a mast with square sail and found that he had a vehicle that would travel beautifully before the wind. A model of this sailing railroad was sent to the Czar of Russia; this suggested the thought which led to the building of the first railroad from St. Petersburg to Moscow.

But as the sailing car could only be used when the wind was abaft the beam, it very soon became clear that the sails could not be adopted as motive power for a railway. Then a horsepower motive from the treadmill pattern was tried, but this had only partial success.

It was then suggested that locomotives such as Stephenson was building for the Liverpool and Manchester Railway of England might do, but word came over that Stephenson had declared that a locomotive could not run on curves of a radius of less than nine hundred feet; there would have to be curves of four hundred feet radius in order to get it around some of the curves in America. So the locomotive idea was abandoned, until Peter Cooper of New York, afterward famous as a philanthropist, got the idea that he could knock together a locomotive that would get around the sharp curves all right. He came to New York, bought an engine with a cylinder three and one quarter by fourteen and one half

inches and, returning to Baltimore, got some iron and built a boiler about as large as a good-sized wash boiler. He wanted some iron pipes for boiler flues; but as none were obtainable, he used some old musket barrels for the purpose.

Thus it was that the first American locomotive was built in a carriage maker's shop. However, as it was not intended for actual service but only as a working model to show the directors what could be done, first honors properly belong to the "Best Friend of Charleston," an engine which was built for regular daily operation, although it did not make its initial trip until sixty-six days after Cooper's locomotive appeared. Cooper's working model was so insignificant in appearance that he christened it the "Tom Thumb."

On Saturday, August 28, 1830, with six men on the engine, which was no bigger than a hand-car of today, and with thirty-six men on the car attached, the first trip by an American-built locomotive was made. The run to Ellicott's Mills, thirteen miles, up an average grade of thirteen feet to the mile, required one hour and twelve minutes. The return was made in fifty-seven minutes. In some places, a speed of eighteen miles an hour was reached.

These first two railroads, such as they were, served as models for the construction of the first railroad designed for general transportation business. The first act of the Baltimore and Ohio Railroad, after its organization, was to send its experts to study these lines for ideas to be applied in building their own road. From this time forward, the builders of American railway equipment were to be no longer slavish imitators of things English.

It was fifty-six years after Watt had patented his steam engine, forty years after the time when the astounded legislature of Pennsylvania had ignored the request of Oliver Evans for a patent on a steam wagon as the hallucination of a disordered mind, that the charter for the first railroad in America was drafted. In America, progress in engine-building had been so slow that twenty-seven years before that pioneer railroad company was organized, the Philadelphia Water Works were operated by a wooden boiler supplying steam at two and half pounds pressure to an engine built chiefly of wood with a copper cylinder as large as a good-sized modern boiler.

The first small locomotives ever seen in the United States were ordered by the Delaware and Hudson Canal Company in 1822.

Three of these locomotives were from the works of Foster, Rastrick and Company of Stourbridge, England. The "Rocket" was built by the famous Stephenson. The first of these locomotives arrived in New York in January, 1829; the last one, in September of the same year.

Steam Roads in America and England. The first steam railroads, both in England and America, were regarded primarily as passenger carriers, and so it is that the first actual railway equipment built consisted of passenger cars. But when these had been developed to a certain point, the same principles that had made them successful were applied to cars for carrying freight, and most of the mechanical features of each were developed concurrently on both classes of equipment.

The early history of railroads in America is so woefully lacking in authentic records that it is most difficult to trace the long series of advances made in capacity, in size, and in variety of cars that were built for the early railroads. An adequate history of the freight car or of the construction of railway equipment, either in America or in England, has never been written and probably never will be.

First Freight Cars. After the colliery cars had been built and had been for some years in use, prior to the advent of steam, the first freight cars devoted to the handling of miscellaneous freight in England consisted simply of a bed or platform on which the goods were stacked and covered with tarpaulin. There was also a gondola type of car with slatted sides and ends. This open car was undoubtedly the forerunner of our modern flat car; even today it is this type of car that answers the general traffic requirements in many foreign lands, as distances there are short, freight is dispatched with great celerity, and it is very often loaded and unloaded on the same day.

The point of departure between the English and American practice in the methods and plans of construction of both passenger and freight cars came because of the prevalence of steep grades and sharp curves on the early railroads of this country; and it was the greater distances over which freight and passengers had to be hauled, coupled with the greater volume and diversity of traffic necessitating distribution over vaster areas, that required in the United States the building of larger and more varied types of freight cars.

Prior to the year 1870 — these were the days before American railroads had reached the period of adolescence — cars used on our railroads were not only of the lightest possible construction but they were also characterized with a great variety of shape and design. Cars for hauling freight were called " burden cars " and in those days they were really nothing more than boxes, a little longer than their width, with four wheels to the car, and a total capacity of three or four tons.

Fig. 1. — An early type of double-truck box car, built in 1878 by Michigan Car Company, afterward the Michigan Peninsula Car Company; and finally the American Car and Foundry Company.

A rapidly growing population and a gradual widening in the areas of distribution, together with constantly increasing traffic demands upon the early railroads, demonstrated the necessity for an increase in the unit capacity of freight cars. The introduction of four-wheeled trucks not only rendered this possible, but it also marked the first step in the evolution of a distinctly American type of freight car.

The year 1867 marked an epoch in the annals of American railway car-building; for it was on Washington's birthday of that year that there appeared before the newly formed " Master Car Builders Association," a young man who was destined to become one of the world's greatest car builders; the man who visioned the possibility of giving to the American public comfort and luxury

in travel — George M. Pullman. It was this same period that brought forward another advance of great significance: the invention of the Westinghouse Air Brake, which was successfully applied in the winter of 1868–69 to eight cars and an engine on the Steubenville accommodation train on the Pittsburgh, Cincinnati, and St. Louis Railroad. The Westinghouse Air Brake opened the way for the safe handling of trains at increased lengths and for cars of higher capacity. Its value in operation was unquestioned after a demonstration in 1887 by a test of fifty freight cars (a train of 1900 feet in length, and a weight of 1,700,000 lbs.), which was brought to a stop from a speed of 20 miles an hour in a distance of 171 feet. To stop the same train at the same speed by the use of the hand brake hitherto employed, which was operated by five men, all ready for simultaneous action, required a distance of 1563 feet.

Farther back in the years than this, however, occurred the birth of another idea in railway transportation. It was in 1857 when an Eastern railway had 30 box cars fitted with double sides, roofs, floors, and the interstices packed with sawdust. This, crude as it was, was the granddaddy of the refrigerator car. In 1871 there was introduced a real refrigerator car equipped with ice bins, or compartments, at the ends of the car, and it was about 1881 that the first stock car with watering troughs and feed bins was constructed.

Another great stride forward in the building of special railway equipment for the roads was the introduction of the automatic coupler, extending over a period from 1863 to 1888 and first tested by the Pennsylvania Railroad in 1883; this was followed by the test of 100 sets of couplers by the C. B. & Q. Ry. in 1884. This test, proving highly satisfactory, marked another great forward step in the safe and prompt handling of freight equipment, obviating the need of a man between the cars in coupling.

High speed and the quick handling of heavy equipment were made possible through the advent of the air brake and the automatic coupler, and these two factors soon made apparent the utter inadequacy of the wooden frame car, so that there soon came about a complete revolution in the car-building industry by the change from wood to steel cars.

Wooden draft timbers bolted to the bottom of wooden center sills pulling out, wooden center sills breaking at bolsters, and the

difficulty in obtaining an adequate supply of timbers for the gradually increasing size of cars, made imperative a change to stronger and more readily obtainable materials. Thus, born of necessity, came draft sill reinforcements of steel, steel underframes for wood cars, steel frame cars, and all-steel cars.

First Steel Cars. The use of steel in the manufacture of railway cars is a comparatively recent growth. It was in the early nineties that Mr. C. T. Schoen began making pressed-steel car shapes in his little plant in lower Allegheny, and for some years he supplied the railroads with pressed-steel center plates, side bearings, stake pockets, push-pole pockets, etc., for use in connection with the construction of wooden cars. It was not until 1895 that Mr. Schoen conceived the idea of building steel cars on a large scale. The following year the first steel cars were ordered by the Pittsburgh, Bessemer, and Lake Erie Railway, and shortly after by the Pittsburgh and Western and the Pittsburgh and Lake Erie. The demand for this type of car grew rapidly as its features of economy and greater safety became apparent.

In the meantime, a part of the history of the development of railway equipment to meet modern needs had to do with the transportation demands which required the development of specialized types of cars for transporting, efficiently and economically, the varied products of industry. Thus it was that the engineering skill and knowledge of the car-builders were successfully applied in designing cars especially adapted to particular classes of traffic; so that there are today, in place of the one-type all-purpose car that was first used, specially designed freight cars known as box cars, furniture, automobile, single and double-deck stock cars, refrigerator cars, heater cars, ventilator cars, gondola, hopper, ore, mine, tank, logging, poultry, flat, rack cars, and others which supplement by certain variations these principal types, so that every need of transportation in every industry may be fully met.

The first steel cars were built to carry coal and probably 85 per cent of these are still running, after twenty years of service, in and out of the Pittsburgh district. The large increase in railroad cars of heavier capacity which enable the increasing volume of tonnage to be more economically handled on congested railways is undoubtedly due to the advent of the steel car, and this, in turn, has had a marked effect on railway construction. The introduction of the 100-ton capacity car, made possible only through the use

of steel in car construction, has necessitated heavier bridges, heavier rails, and heavier locomotives.

The use of steel in car construction was probably first introduced in 1874 in the form of channel iron for sills and bolsters in a car operated in stock service on an eastern line. In the late seventies or early eighties, a peculiarly shaped iron-body hopper car, known from its shape as a three-pit hopper, was introduced. This had only 13 tons' capacity, weighing 12,800 lbs.

It was not until 1894 that the modern steel car became a recognized unit of American railway service. In that year, the Car-

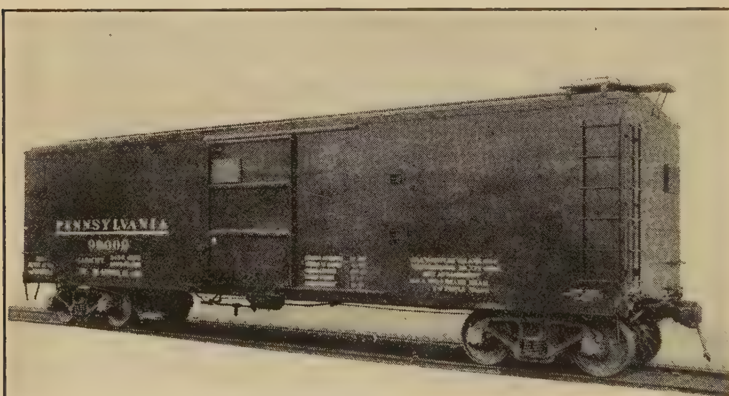

FIG. 2. — Latest type of modern all-steel box car built by A. C. F. A natural evolution in equipment construction.

negie Steel Company had six flat cars built, and in 1896 the Keystone Bridge Company built two 100,000 pounds' capacity steel hopper cars which were exhibited at a convention in Saratoga and afterwards placed in service on the Pittsburgh, Bessemer, and Lake Erie. This railroad, in 1897, placed the first large contract for building steel cars in this country when 1000 cars were built, 600 of pressed steel and 400 of rolled structural shape. From that period forward, progress in the construction of steel freight cars has been rapid.

The credit for the development of many of the minor details of improved railway equipment belongs to the organization of the Master Car Builders Association to whose constructive work is due the first step in the standardization of interchangeable parts of American cars. In its " Standards " and in its " Recommended

Practices," this Association has created a monument appropriate to the purpose of its organization, viz.: "the formation and dissemination of correct views regarding car construction." So it is that railway equipment builders, working to a common end, have seen in the manufacture of car parts: 56 kinds of journal boxes reduced to five sizes and one interchangeable type; 56 kinds of axles reduced to five sizes, with one interchangeable type; 26 kinds of couplers reduced to one; 20 kinds of brake shoes reduced to one; 27 kinds of brake heads reduced to one interchangeable standard; wheels reduced to 3 types and 4 sizes; brake beams, all interchangeable; grab-irons fixed by law; and so on.

Passenger Car Development. The development of passenger cars and equipment in America has been coincident with the remarkable progress recorded in the improvement and utilization of freight cars. Records indicate that the first car on an English railroad devised solely for the transportation of passengers bore a striking resemblance to a small log cabin on wheels, which was drawn by a horse. It was also customary, in England, for persons of quality desirous of traveling by rail to place their own carriages upon a platform fitted upon a truck which ran on the rails.

In the United States, the old Concord Stage Coach was adapted to railroad usage by the application of flanged wheels. Other accounts depict the first passenger cars as nothing more than clumsy covered box wagons, fitted with planks for seats; while the first passenger car on the Baltimore and Ohio Railroad was like a small clapboarded wagon on wheels, similar in appearance to a North Carolina mountain hut. The first cars were propelled by horse power, with a capacity of 12 to 24 passengers.

The introduction of the bogie truck by Ross Winans on a B. and O. passenger car about 1831 ushered in the first eight-wheeled car and marked the beginning of the radical difference between the English and the American cars. The ability of this eight-wheeled car to round curves, which abounded on most railroads in those days, led to its adoption about the year 1835.

The typical eight-wheeled passenger car coach built between 1840 and 1850 was devoid of springs aside from the ordinary rubbers in the pedestals; the only ventilation was by means of a 10-inch flue in the center; the windows did not raise but the panel between them could be lifted; there were no lighting arrangements except a candle placed at each end of the car; heat was supplied

by one stove; there were no closets, lavatories, or water coolers; the wheels were outside of the bearings on the original trucks; the seat frames were of iron with walnut arms and upholstering of plain leather; and the body of the car was 36 feet in length, 8 feet 4 inches in width, and 6 feet 4 inches in height. While the arrangements of this car indicated marked progress in passenger-car construction, it was conspicuously lacking in a number of modern improvements.

As regards mechanical and structural features, passenger-car development proceeded very closely along the lines followed in the evolution of the freight car. The original wood frame passenger cars were improved by increases in size and carrying capacity, so far as was consistent with safety in connection with wood construction. Next came the composite steel construction, and there was finally evolved the all-steel passenger car; and the gradual transition from wood to steel construction assumed such proportions that a new industry in connection with car building was virtually created — the production of steel cabinet work for the interior finish of the car.

In this, one of the most important and progressive forward movements in the history of the Railway Equipment industry, the American Car and Foundry Company played a leading part.

The first steel passenger cars built by the American Car and Foundry Company in 1904 were furnished to the London Underground Railway, although at that time the American Car and Foundry Company was already working on an order for non-inflammable steel passenger cars for the Interborough Railways. The work was carried on by the engineers of the New York Subway under the direction of Mr. George Gibbs, who was not only Consulting Engineer for the Interborough, but was also serving in a like capacity in regard to the necessary equipment for the Pennsylvania tunnels. Mr. Gibbs succeeded in designing a passenger coach built almost entirely of non-combustible materials.

First All-Steel Cars. In February, 1904, the Interborough Rapid Transit Company placed in service on its Second Avenue line an experimental all-steel coach of a type which it hoped to use subsequently in the subway, with such changes as tests on the car might indicate as being desirable. This was the car built at Altoona, Pa., in the Pennsylvania shops during the previous sum-

mer and fall and which was designed primarily for use in the Pennsylvania-Manhattan tunnel. It was described as follows:

The car was 51 ft. 2 in. long over platform sills, and 8 ft. 7 in. wide over sheathing. It had a seating capacity for 54 passengers, the seats being arranged with eight transverse seats in the center. The underframe consisted of one-beam center sills and angle side sills which were trussed. Post, braces, and carlines were of structural steel shapes and the sides of the car were sheathed with steel plates. The floor consisted of corrugated iron laid directly on the underframing over which, in turn, was laid "monolith."

Fig. 3. — First all-steel passenger car, built by A. C. F. This was built for the London Underground Railway.

Headlinings and panels were of "cellinite," a flexible tough asbestos board made by H. W. Johns-Manville Company. The seat frames were of steel. The only inflammable material used was the wood of the window sashes and doors, and the cane of the seats. In a few days the trial car had performed satisfactorily and 200 coaches of similar construction had been ordered from the American Car and Foundry Company. This marked an advanced epoch in the progressive development of railway equipment.

It is curious to note that the first thought of providing steel passenger cars came about through the need for a coach that would be bullet-proof; this was due to the depredations on the Western Railroads by the notorious train robber, Jesse James and his associates.

According to a report of a special committee on steel passenger cars, which was directed to investigate the subject by the Master

Car Builders' Association, the report being made in 1908, it was found that the possible use of metal for the construction of passenger cars had been considered as early as 1854. The designs of such cars were prepared by B. B. LaMothe, in which the superstructure was of metal but the ends and sills remained of wood.

At the convention of the Master Car Builders' Association in 1906, the American Car and Foundry Company exhibited a sample of an all-steel car, being the lot which they were building for the New York Central and Hudson River Railroad Company. This car was designed for service over tracks within the New York Central Electric Zone, and for operation in trains by the Multiple unit system. The general dimensions of these cars were such as to compare favorably with those of equipment for steam service, the cars being 60 feet long over buffers; 13 feet, 9½ inches high from top of rail, and 9 feet 8½ inches wide. The total weight in running order, including motors and electrical equipment, was 105,500 pounds. These cars were equipped with wide vestibules and had toilet facilities similar to steam cars.

The steel passenger car, having been thus given an opportunity to prove its practical worth, the American Car and Foundry Company constructed steel coaches for the Long Island Railroad Company. A summary of the report made to the Master Car Builders' Association in 1904 shows that, at that time, the steel car equipment for steam railroads then in service or under construction was composed of about 380 units. Nine railroads and four or five car companies figured more or less in the operation and production of these cars, with the American Car and Foundry Company well in the lead.

Naturally, the greatest development was shown in the East, undoubtedly stimulated by the many tunnels in and around New York through which the cars of steam railroads had to pass, and in the construction of which cars, steel and fire-proof material were considered essential in order to insure safety.

Within two years from the time when the first steel passenger car had been built, the American Car and Foundry Company had furnished steel passenger cars to the Interborough, the Long Island Railroad, to the Santa Fe, the New York Central, New Haven Railroad, to the Hudson Company, and to the Pennsylvania Railroad.

With the advent of the steel passenger car came the modern

evolution in interior decoration. From the wood interiors of the early days, which were entirely devoid of any attempt at embellishment, there came the era of highly ornate style with inlays, heavy carvings, and other embellishments, which was succeeded by gradual reversion to plainer styles with less ornamentation. Finally, there was adopted the plain, sanitary, and modern steel finish of today with a minimum of decoration.

In answer to the objection that has been made that modern American passenger equipment has grown to be too heavy, builders point out that safety is today the first consideration, and high speed has made it necessary so to construct cars that their various parts must be heavy enough to provide an ample margin of safety and strength, not only to resist the sudden shocks and distortion stresses on the structure which use imposes, but also to get ample provision against deterioration and to reduce the cost of maintenance to a minimum. Light cars have proved unequal to the requirements of American passenger travel. The weight, therefore, of modern passenger equipment is the result solely of service demands, plus the safety and comfort of passengers; and these requirements are an adequate defense against the charge of too heavy construction.

When it is considered that the modern passenger car is equipped with electric lights, steam-heating systems, toilet and washroom facilities, supplied with running hot and cold water, coolers for drinking water, drinking-cup vendors, electric fans, upholstered seats with headroll and automatic foot-rest, continuous parcel racks on each side of the car, window shades, windows that can be raised and lowered, exhaust ventilators in deck sash in body of car and in men's and women's saloons, an interior finish of mahogany color, etc., it will be seen that the all-steel passenger coach, in its present stage of development, embodies the maximum of safety, comfort, and convenience, in so far as engineering ability, mechanical ingenuity, and scientific research can contrive.

CHAPTER XVIII

RUBBER

By P. W. Litchfield[1]

The Romance of Rubber. There is romance in the story of rubber.

Its discovery was almost contemporaneous with the discovery of America. One legend is that Christopher Columbus, on one of his voyages, found West Indian natives playing a sort of game with balls having surprising resiliency.

There are curious chapters in the history of rubber cultivation — for example, that of the South American Indians making their way through the jungles of the Amazon, stopping before certain trees, tapping them, coagulating the milky juice over a slow smoky fire, carrying great balls of rubber on their backs down to the rivers, paddling it in canoes, or shipping it on river boats down to the main export ports 2000 miles away.

There is the story of how this substance, now having a thousand uses, for three and a half centuries defied the ingenuity of chemists and manufacturers; and another of a pinched and haggard inventor, his clothes ragged, his fingers stained with acids, toiling away for years in rickety sheds, in his bare kitchen, in the boiler room of small factories at night after the employees had gone home, seeking for nine years to learn the secret of rubber.

The story of a vast experiment in agriculture, the setting up of a new industry involving hundreds of millions of dollars within a quarter century; the story of a giant trade in basic commodities between two hemispheres; the story of violent price fluctuations, of fortunes made and lost, of price movements as flexible and resilient as the material itself. International controversies over rubber — United States producing 2 per cent of the rubber of the world and consuming 75 per cent; the relationship of this matter to

[1] President, The Goodyear Tire and Rubber Company.

the national defense. (The *Deutschland*, first German submarine to cross the Atlantic to America, carried rubber back as its chief cargo.)

The Character of Rubber. The strange character of the material itself — " flexible metal," Charles Goodyear called it — something that can be spun out to the gossamer-like fineness of a toy balloon and return to its original dimensions, yet with the strength and toughness of a battery box or a solid tire.

FIG. 1. — Native gathering latex on well-developed rubber plantation. The illustration shows the herring-bone pattern of tapping.

Rubber is non-compressible. Under heat crude rubber will flux and will flow evenly and truly into the crevices of strange-shaped molds and take whatever shape you ask. But if there is ever so little surplus rubber placed into the mold and you have not provided pin holes for that surplus to escape, the steel molds themselves will crack and break before they can be forced to close over this material that seems infinitely flexible and malleable.

Spread rubber over cotton cloth and the fabric becomes waterproof, air proof, gas proof, offering a material for the making of clothing, footwear, packing and washers for machinery, automobile tires, balloons and airships, compressed air hose. The sur-

geon puts on rubber gloves and gains immunity from deadly germs. The electrical worker protects himself similarly from electric shock.

Within the past two years the oil companies have learned to utilize rubber in reducing gasoline losses. Gasoline volatilizes during the day, condenses at night. Great " breather bags " of rubberized fabric, housed in sheds alongside gasoline storage tanks, now draw these fumes into their lungs as the temperature rises and expel them back as the temperature falls.

Early Development. The articles in commercial use in which rubber is used run into an amazing total, so that it is hard now to see how we could keep house, industrially or literally, without it. Yet its beginnings as a commercial product go back hardly 100 years, its large-scale expansion only to the beginning of the 20th century, and its emergence as a billion dollar industry only to the years following the World War.

Until 1839 rubber remained as a curious plaything of scientists, an enigma and a challenge to the laboratories. It was commercially valueless because of one fatal defect. No matter how cunningly compounded and fabricated, it would not stand the weather. It grew sticky and melted under heat, grew brittle and cracked in the cold. It was fair-weather material.

A Connecticut Yankee found the solution.

Charles Goodyear's discovery of vulcanization, the process that made the rubber industry possible, was in a way accidental, as many other great discoveries have been. But as in other cases it was one of those accidents that seem to happen only to men who have already devoted vast effort and energy and patience to the search, and to men observing enough and acute enough to recognize the goal when they have come to it.

One might vision a kindly God watching the upward struggles of humanity, nudging the elbow of the tired seeker, whispering to him: " There it is, don't you see? The thing you have been looking for, right under your eyes!" Goodyear, once the spell of rubber had caught him, had given up his mercantile business in Philadelphia, had used up his own resources and all the money which friends and relatives could be persuaded to advance, had seen his family go poorly clad and hungry, and had himself been imprisoned for debt in his search for the secret.

A batch of rubber and sulfur thrown into the fire and reclaimed from the ashes one morning gave Goodyear the clue. Something

had happened: a basic change had taken place. The rubber had "vulcanized." Sulfur plus heat was the answer.

Just exactly what happens to rubber during vulcanization, whether a chemical change takes place, or a change in structure, in the arrangement of the atoms or molecules making up the rubber, or something still different, is a point about which science has not even yet made up its mind. The important thing is that after vulcanization, rubber remains constant, indifferent to changes of heat and cold. It becomes "fixed."

To complete the story of Charles Goodyear, it may be noted that he won great fame as a result of his discovery; that he made and lost two fortunes from it; that he won a great patent suit with Daniel Webster defending and Rufus Choate opposing; that he staged great expositions in London and Paris showing his products; that he wrote out a list of articles which could be made of rubber, a list to which, with the exception of the pneumatic automobile tire, the world has been able in the century since to make but few additions; that he again saw the inside of a debtors' jail cell before his death; and that he passed away $190,000 in debt as a reward for his contribution to the world. His death took place in 1860 at the age of 51.

Even before Goodyear's discovery of vulcanization, factories had sprung up to try to make rubber goods. As early as 1823 the Scotsman MacIntosh had discovered a way to spread rubber on cotton fabric and make waterproof cloth.

Efforts to bring rubber manufacture to this country, one of the first being at Roxbury, Mass., in 1832, proved unsuccessful, due to the wide range of temperature from summer to winter. Goodyear himself, and many others, tried to manufacture rubber goods in this country prior to vulcanization but met usually with financial disaster. With this difficulty removed, however, factories sprang up all over New England and the east. Watertown, Chicopee Falls, Boston, Naugatuk, Passaic, many other cities found the manufacture of rubber goods, especially rubberized clothing and rubber boots and shoes, a highly successful industry. The first golf ball utilizing rubber was made by the principal of a girls' school in New York State in 1845.

Rubber factories gradually spread around the world. Dunlop, an Irishman, made a rubber tube in 1888, inflated it with air, put it on a bicycle and the pneumatic tire was here. The United

States Rubber Company was organized in 1892, taking in a number of plants as far west as Indianapolis and Detroit. Akron, Ohio, was becoming known as an important rubber center by the beginning of the century. Dr. B. F. Goodrich, a Civil War doctor with a taste for manufacturing, went West in 1870, looking for a site, and picked Akron.

The Goodyear Tire and Rubber Company, named in honor of the inventor, was started just before the turn of the century, manufacturing carriage tires and bicycle tires. The Firestone Company started in 1900. The Miller Rubber Company had begun to make rubber gloves and surgeons' supplies in 1892. Other factories followed, until Akron became the rubber capital of the world, using one third of all the rubber produced.

By the time of the Civil War the rubber industry was doing a $3,000,000 volume annually. The Spanish-American saw it reach $100,000,000. Its expansion to the billion mark, with 475 factories producing rubber goods, was to come within the present century.

The Use of Rubber in the Automobile Industry. Ford and Haynes and Coffin and other little-known men were tinkering away in out-of-the-way sheds and factories, over gears and motors and wheels and ratchets, making curious contrivances. Carriages that required no team to pull them were appearing on the streets and frightening horses, and wiseacres were scoffing at them and proving around the stoves of country stores that the fool things weren't practical.

The automobile opened a new and immense field for the manufacture of rubber goods, a field that was to become larger than all the others combined. The world used but 27,000 tons of rubber in 1900, but in the quarter-century following this total had grown almost twentyfold, reaching an aggregate of 533,000 tons. Part of this increase was due to the enlarging market for rubber goods in industry and in consumer use, but the automobile chiefly explains the expansion.

Reports of the Rubber Association, which includes 82 per cent of the industry in the United States, show that of the $1,200,000,000 worth of rubber goods produced in 1926, $866,000,000, or about 72 per cent, represented automobile tires, tubes, and accessories, the balance including boots and shoes, 9.5 per cent, mechanical rubber goods (chiefly belts, hose, and packing), 8 per cent, druggists, and surgical supplies 3 per cent, and miscellaneous. Waterproof

clothing, once the back log of the industry, now makes up less than 2 per cent of rubber manufacture in the United States.

Since the automotive industry fills so large a place in rubber manufacture and since that industry went forward in America much faster than in any other country, building and using several times as many cars as all the other countries combined, the rubber industry went forward much faster in the United States than abroad. During 1926, 64 per cent of all the rubber produced in the world was brought to America.

However, the obligation of the rubber industry to the automobile was by no means one-sided. If the internal-combustion engine made the automobile possible as a practical carrier of people and goods, the rubber tire made possible the thousands of improvements and refinements in automobile building that made it the vehicle for the millions.

In 1900 the only application of rubber to transportation was for bicycle tires, small solid-rubber tires for the carriages of the fashionable world, and solid and some pneumatic tires for racing sulkies. The development of the intricate and delicate mechanism we call the automobile without rubber tires to cushion it from the thousands of jolts and jars of the highway, and at the relatively high speeds that even the most conservative municipality today permits, would be unthinkable. The occasional automobile rattling along a paved street on its steel rim en route to a garage furnishes evidence of the importance of the contribution that rubber makes to the automotive industry.

An automobile rides on compressed air, the most efficient shock-absorber yet found. Men have tried to find better cushioning devices, but to date no better medium has been discovered than air to absorb the hammering blows of the roadway.

However, compressed air in an inelastic container would be no whit better than a solid metal-shod wheel. It is the elasticity of the rubber tire that permits the compressed air to function. Rubber is the only material that has this elasticity combined with strength. The ability of rubber to prevent diffusion of air or gases and its ability to give and then return to its original contour — plus its capacity to take punishment (it has been estimated that every part of the tread of a well-made tire comes into violent contact with the road 10 to 15 million times before it wears out) — make rubber an ideal material for tires.

The automobile began to swing into its stride, to give the world some indication of its future importance, by 1906. By 1910 men were talking seriously about a saturation point — a saturation point that was to recede on approach like the fabled pot of gold at the rainbow's end.

Wild Rubber Supplanted by Plantation Rubber. However, the advances that the industry was making by that time had already begun to have a serious effect on the matter of crude rubber supply, and were shortly to change the rubber map of the world. As late as 1912 95 per cent of all the rubber used was wild rubber, mainly from Brazil and the African Congo, while 5 per cent of it came from rubber plantations in the Far East. Within ten years that situation was reversed, with 95 per cent of the rubber coming from the plantations and 5 per cent wild rubber. The automobile had a good deal to do with this.

Back in 1876 an enterprising Englishman, Henry Wickham (later Sir Henry), secretly exported from Brazil 7000 seeds from the Hevea (rubber) tree and shipped them to London, where they were planted in Kew Gardens. Presently the young sprouts were transported to Ceylon and set out there. They grew and flourished. Some of them are said to be still standing.

The British government sought to extend the planting of rubber trees throughout its possessions in the Far East. In the course of time plantations of considerable size had sprung up in Ceylon, India, the Straits Settlements, presently extending into the Dutch possessions in Sumatra and Java. Crop failures in coffee later gave impetus to the movement, discouraged coffee planters substituting rubber trees for coffee. As the Amazon Valley was losing rubber it secured coffee in exchange, the most dramatic and far-reaching exchange of basic commodities in economic history.

It was a striking coincidence that the rubber plantations had just become important in the East by 1910 when the automobile was coming into wider use, and when an acute shortage of rubber was imminent. The requirements of the automobile, added to the needs for general manufacturing, were demanding more rubber than the jungles of the Amazon and the Congo could supply. The law of supply and demand came into play; the price went up to \$1, \$2, even \$3 a pound by 1910. The men who had invested in rubber plantations in the Middle East made fortunes, since the cost of production was somewhere around 25 cents a pound.

Plantation rubber in the next ten years all but supplanted wild rubber in the markets of the world because the supply could be indefinitely expanded in plantations, but could not be greatly increased in the forests without exorbitant cost. Plantation rubber was no better than the wild variety beyond the fact that it was packed and shipped in better shape and was freer from foreign particles and dirt. But rubber trees in the jungles may be scattered as far as a mile apart and the number of trees that a single

FIG. 2. — "Budding" a slip from a high yielding tree on to a low yielder, to increase the output.

native can tap and draw latex from is limited, whereas on an efficiently laid out plantation a single native can cultivate and tap as many as 400 trees a day. And new plantation acreage may be planted as needed.

The fortuitous arrival of plantation rubber in the market stopped the runaway price movement, and the rubber planters, encouraged by the large profits, became very busy clearing new areas and setting out additional plantations, so that in the next several years the price scaled down to a more reasonable relationship with the cost of production. More important to the growing automobile

industry was the fact of a rubber supply that could be expanded to meet its maximum requirements. The industry was not to be held back by a shortage of rubber.

Processes of Rubber Cultivation. A word might be said here about the processes of rubber cultivation. A rubber tree begins to bear within six or seven years and continues to produce rubber in increasing quantities for several years. The life of a rubber tree is still not known, as some of the earliest plantation trees are

FIG. 3.—Native arriving at plantation headquarters with latex from rubber trees.

still producing. The rubber comes from a milky liquid called latex that flows from just inside the bark of the tree. A thin strip of bark is pared off about half way around the tree and about three feet from the ground to start the flow of latex. A cup is placed to receive the fluid as it exudes from the tree. When the tapping cut has reached the ground, the other side of the tree is tapped, permitting new bark to grow on the bared surface.

This latex coagulates, curdles somewhat like sour milk, and this semi-solid portion is rubber. It is run through small mills and sheeted out, dried, folded into sheets, and packed in bales or boxes, and is then ready to be sent to market. Acetic acid is now generally used to hasten the process of coagulation. The United States Rubber Company also ships raw latex in tanks. However, the usual process is to coagulate the rubber on the plantations.

To get some idea of the vast extent of the rubber-growing industry, one may visualize the fact that a single rubber tree will produce about three pounds of rubber a year and that the world used industrially more than 500,000 tons of rubber in 1926.

The British estimate the cost of bringing a plantation into bearing at $300 an acre. More than 4,000,000 acres have been planted to rubber in the Middle East in the last 20 years, representing an investment, according to British Rubber Growers Association figures, of close to $1,000,000,000. Consequently, any wide fluctuation in the selling price of this key commodity, foreign controlled, some 12,000 miles from the United States, is certain to have far-reaching consequences. Rubber has been peculiarly subject to such fluctuations.

Rubber-growing differs from wheat farming or cotton raising in that the trees do not produce for about five years after planting and do not reach full maturity until several years after that. Consequently, high prices cannot immediately stimulate an increased acreage, nor is the output reduced when the market is down. Less dependence by manufacturers on market conditions and greater control by manufacturers of a larger part of this raw material would no doubt be of great assistance. These were the factors that made 1920 and the years immediately following especially difficult.

The Post-War Crisis. The blow fell suddenly in the rubber manufacturing industry. By June the demand for tires and other rubber products was proceeding at the breakneck pace at which it had gone since the post-War expansion started. By November the market had shrunk almost to the vanishing point.

A rubber manufacturer must contract for his crude rubber some four months ahead, to allow time for delivery. Due to tremendous demand for tires from the public and from car manufacturers during the first half of the year, the tire industry had huge quantities on hand and under order. Stocks deemed adequate only for current immediate needs in June became by December more than they could use up in months. Tons of additional rubber were en route to them. Rubber became a drug on the market. The price collapsed from around 55 cents a pound to 11½ cents. The trees continued to produce latex in full volume regardless of markets and prices. Production could not be restricted.

For two years, while manufacturers were slowly absorbing their

surplus stocks, crude rubber sold below actual plantation costs. Staggering losses were taken by producers and manufacturers. The latter wrote down their inventories to the market and absorbed the difference. Small companies closed their doors. Large and well-financed companies narrowly averted disaster. To understand the plantation situation, a short summary of national ownership is necessary. British growers owned close to 60 per cent of the plantation acreage in the Far East, the Dutch about 15 per cent American, French, Japanese, and native ownership making up the balance. Native ownership was not inconsiderable since it represents the aggregate acreage of thousands of natives with two to a dozen acres planted with rubber.

The American-owned plantations were principally those of the United States Rubber Company, which began operations in the Far East in 1907 and in 1920 had some 60,000 acres planted, representing an investment of $19,000,000; and the Goodyear Tire and Rubber Company, which bought a concession of 20,000 acres in 1916 in Sumatra, had only about finished planting.

While Great Britain politically controlled only 60 per cent of the actual acreage, 75 per cent of all the rubber exported to the United States came through British channels. The government felt keenly the necessity of providing some relief.

While the financial losses to plantation owners and shareholders were mounting, there was still another peril in the situation. Though it takes several years to bring a plantation into bearing, it may go back to jungle within a year unless it is rigorously cared for. With trees planted as thick as 200 to the acre the stand of rubber demands all of the fertility that the soil contains if the best results are to be obtained. Any loss in planted acreage would take years to make up.

Attempts were made to reach an agreement among the planters for voluntary restriction of tapping, but the ownerships were so widely held that this had negligible results. The British government was appealed to. Rubber stocks were almost as widely held by British investors as steel or railroad and industrial stocks in this country, and these shareholders now saw their dividends stopped and huge losses mounting up.

The Stevenson Act. Sir James (later Lord) Stevenson was appointed chairman of a committee of Parliament to study the situation and suggest a relief. Voluntary restriction having failed,

the Stevenson commission recommended, and the British Parliament enacted into law, a plan known as the Stevenson Act, aimed to regulate the export of crude rubber from British possessions so as to meet the reduced demand and thus bring about normal price levels. The Stevenson plan, which went into operation November 1, 1922, set up the actual plantation output for the year ending October 31, 1920 (with corrections for planting that came into bearing thereafter), as "standard production."

A certain percentage of this "standard production" was permitted to be exported in each quarter year, depending on the average price of rubber in the preceding quarter. An average price

FIG. 4. — Natives folding sheeted rubber after drying, preparatory to crating and shipping.

of 1 shilling 3 pence to 1 shilling 6 pence (approximately 30 to 36 cents) during any quarter would bring about the release of an additional five per cent of standard production. An average price of 1 shilling 6 pence to 1 shilling 9 pence (approximately 36 to 42 cents) would result in the release of ten per cent additional. Inversely, if the price should average less than 1 shilling during any quarter, a reduction of the percentage of release by five per cent was provided for the next quarter. For the first three months of restriction, planters in British possessions were permitted to export 60 per cent of their standard production.

The Stevenson Act aroused considerable protest in this country, many people believing that it was an effort on the part of Great Britain to take undue advantage of her quasi-monopoly of the crude rubber supply. The statement was widely made that she

was trying to pay off her war debt by taxing the American automobile owners.

A British commission headed by H. Eric Miller, chairman of the British Rubber Growers Association, visited this country and sought to alleviate this criticism. They pointed out that new planting had stopped and some acreage had actually gone back to jungle. With demand normal again the acreage would be inadequate and bring about a shortage of supply and higher prices than ever. They declared that the Stevenson Act merely purposed to put rubber at a fair price and stabilize it there, holding that such stabilization was in the interest of the consumer, the manufacturer, and the planter.

Under the Stevenson Act rubber passed the 30 cent mark early in 1923 but fell below it before mid-year, reaching a low of 19 in the middle of 1924. The percentage permitted to be exported was reduced to 55 on August 1, and to 50 in November. By November, however, the price began to rise again sharply, and reached 38 cents by the end of the year. Additional releases were permitted, but since these could be made only quarterly, British possessions were allowed to ship only 65 per cent of standard production in June, 1925. And rubber was selling, by that time, at over a dollar a pound.

The Stevenson Act was not flexible enough to control the situation. Full release of standard production was not made until February 1, 1926, by which time the price had started to slide downward again. Despite the various protests the Stevenson Act was continued, with a modification effective November, 1925, increasing the pivot base price from 30 cents to 42 cents.

There were other reasons for this rise in rubber prices beyond legislative ones. Restrictions of supply only accentuated the situation. The demand for rubber had been quickening; European countries were getting back to normal, were using more rubber; surplus stocks had been consumed; American manufacturers had absorbed their 1920 inventories, but had been crippled financially in the process and had been buying for immediate needs; the automobile registration was increasing; and finally the balloon tire had come in, consuming a larger amount of rubber per tire than the old high-pressure tire.

The twelve months of high-priced rubber increased the agitation against the Stevenson Act. Congress protested, talked retaliation,

appropriated half a million dollars for a survey of various parts of the world where rubber might be grown. The President sent Carmi Thompson as commissioner to the Philippines to study, among other things, the possibility of growing rubber there. The Firestone Tire and Rubber Company, after investigating other tropical countries, took over a small plantation owned by an English syndicate in Liberia and leased other large acreage and started clearing, preparatory to planting rubber trees there. Dutch

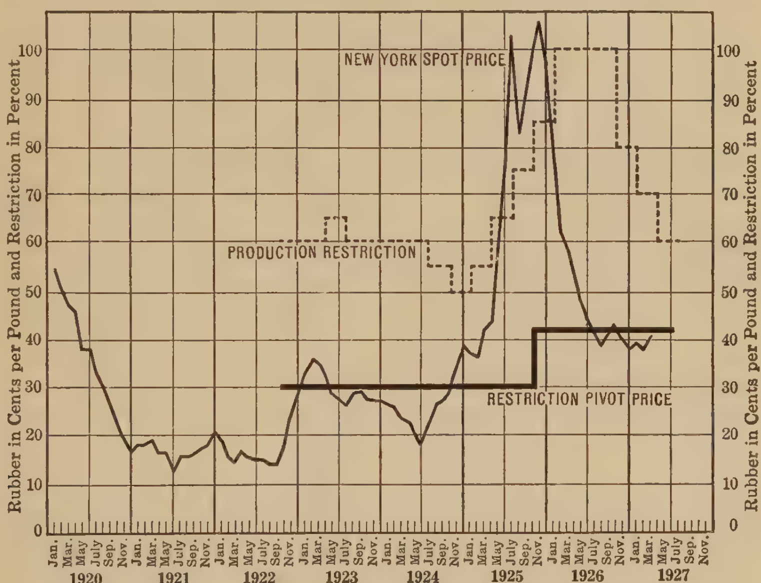

FIG. 5. — Crude rubber prices and restriction.

planters, native owners and others, put in new acreage. Reclaiming of used rubber took on new importance, reclaimed rubber being adapted to wide uses in products not requiring the maximum resiliency of new rubber, such as the best grade of automobile tires and certain other products. The increase in the use of reclaim was from 70,000 long tons (2240 pounds) in 1923 to 165,000 long tons in 1926. Two pounds of reclaim will do the work of one pound of new rubber.

The price situation forced renewed studies of plantation methods, with the result that the output per acre on better-managed plantations was increased from around 350 pounds per year to more than 420 pounds, with the prospect for still further increases in

yield. Production of wild rubber in Brazil and other areas was increased. Renewed interest was created in guayule rubber, which comes from the guayule plant largely found in Mexico. High prices stimulate man's ingenuity and enterprise.

Commissioner Thompson reported late in 1926 that the difficulties in the way of rubber growing in the Philippines were political and economic rather than agricultural. The soil was not unfavorable. Labor costs, however, were considerably higher, making it possible that rubber could be produced profitably in the Philippines only during periods of peak prices unless low-priced labor could be used. Javanese and Chinese labor, widely used in Malaysia, could not be imported into the Philippines by reason of the labor laws of the islands.

Again, insular laws restricted individual holdings to a size of 2500 acres. And 2500 acres is only a drop in the bucket in rubber growing. Political leaders in the Philippines, who were hopeful of early or eventual independence, took active exception to the rubber-growing project, feeling that if large plantations were developed and low-priced labor brought in, America would eventually have so large an interest in the Philippines as to make the prospects for independence highly illusory.

Some sentiment had developed that America should have political control over areas producing necessary commodities, so that in the event of international troubles this country would not be dependent on the good will of other nations for such supplies. That sentiment if enacted into legislation might mean that if America went into the Philippines for economic reasons it might stay in for political reasons to guarantee that such a supply of crude rubber would always be available.

The Stevenson Act was never wholly satisfactory to the British people and the 1926 amendment further increased this criticism among the public, who felt the pinch of higher prices and shareholders who doubted the wisdom of continuing the plan after the 1920–22 crisis had passed. The objections were on several grounds: that the Stevenson Act lessened the incentive to the planter to bring down his production costs by installing better methods; that it tended to keep the price of rubber high, so curtailing demand for rubber goods and permitting similar goods made of other materials to compete successfully with rubber, further shrinking the market; and lastly that shareholders objected to being permitted to

export only part of their output, while Dutch plantations could export all they could produce.

Automobile Registration. The manufacturers of the United States have long been active in export, and American tires can be bought today in practically every country in the world. During the last few years the automobile registration has begun to increase faster outside of the United States than within, bringing an enlarging market for rubber goods.

The Goodyear, Goodrich, Firestone, United States Rubber Co., and Seiberling companies have subsidiary factories in Canada, helping to serve export trade, along with the car owners of the Dominion. The Goodrich company has subsidiaries or manufacturing arrangements in England and Germany, and had a plant in Japan until the 1924 earthquake. Goodyear started factories in England and Australia in 1927.

The world automobile registration for 1927 is set at 27,507,969, of which 5,461,010 is outside of the United States. The principal countries of the world in automobile registration are:

Great Britain	984,000	Spain	85,000
France	901,000	South Africa	81,000
Canada	820,000	Holland	65,000
Australia	361,000	Ireland	64,000
Germany	318,000	Denmark	63,000
Argentine	222,000	Switzerland	51,000
Italy	150,000	Dutch East Indies	48,000
Belgium	130,000	Cuba	45,000
New Zealand	123,000	Mexico	45,000
India	100,000	Japan	35,000
Sweden	99,000		

The principal European companies — Michelin in France, Dunlop in England, Pirelli in Italy, and Continental in Germany — also have important selling activities and some manufacturing activities over the world. Dunlop has a factory in France and Michelin one in England and both have factories in the United States, as well as extensive sales representation in many lands.

The Rubber Industry in the United States. The industry in the United States has been highly competitive, half a dozen large companies leading the field but not dominating it, and with from 100 to 200 smaller companies getting a share in the tire business. Though some consolidations have taken place among the smaller companies, the bigger corporations have maintained independent

existence. Since the formation of the United States Rubber Company, the only noteworthy extensions of this nature have been the Goodrich Company's purchase of the Diamond Rubber Company in 1912 and the Fisk Company's acquisition of Federal in 1922.

With the manufacturing requirements enlarging at a furious pace in the last 25 years, there has been little activity toward control of the raw materials, rubber, fabric, and compound, that go into manufacturing. The two companies which own rubber plantations in the Far East produce only a fraction of their requirements. The long-staple fabric for tires comes chiefly from Egypt, Arizona, and the delta region of the Mississippi, from the fields of thousands of land owners, though the Goodyear Company has its own cotton plantation of 40,000 acres in Arizona and fabric mills in New England and the South, sufficient to make something over half its requirements.

Since rubber goods are sold generally to the very large number of consumers, except for certain industrial uses as power belting and hose, the manufacturers have depended on distributors and dealers to market their goods rather than do so directly.

Sales of automobile tires particularly require accessibility for the purchase and service, so that tire retailing has become an important business, and more than 100,000 retail merchants are handling tires in the United States alone, usually in conjunction with the sale of gas, oil, batteries, and other things accessory to the automobile.

In the case of clothing, shoes, surgical supplies, these too are generally handled through jobbers and by general merchants in connection with other lines of business.

With the rise in size of the rubber industry its concerns have become of interest to a large number of people. The total capitalization of the industry is given at $1,250,000,000. The stocks of the principal companies are listed on the New York exchange and widely traded in, and a large part of the ownership of those companies is in the hands of several hundred thousand small investors.

Rubber manufacture gives employment to about 175,000 people, exclusive of those engaged in growing and handling the raw materials and in selling the finished products.

A great deal of research and development work has been done in rubber in the last 25 years. Secret formulas and rule-of-thumb

methods, all closely guarded, lasted well into the twentieth century but gave way before the physicists, the chemists, and the engineers. Millions of dollars have been spent in research, as the lengthening mileage of the automobile tire bears evidence. For within the memory of most everyone old enough to drive a car, the automobile tire of yesterday was a thing likely to puncture, hard to change, and good for about 2500 miles before it reached the scrap heap. Today many tires will give as high as 30 thousand miles.

Many compounds are used in rubber manufacture: leads and magnesias to add strength and assist vulcanization; carbon black, lamp-black deposit resulting from burning gas fumes, and mica to help it resist abrasion; certain clays to give it body and firmness; talc to prevent it from sticking, and a dozen other little-known compounds and acids are used to accelerate vulcanization and to give various physical and chemical properties desired.

Several universities give special courses in rubber chemistry and chemical engineering, and their graduates find a large and growing field for their efforts.

The rubber industry is one that primarily demands a large amount of working capital. It takes four months to get crude rubber from the plantations of the Far East and nearly as long for tire fabric to go through the complicated process that intervenes between field and factory.

The industry was just getting well out of its financial troubles by 1925, when crude-rubber prices began to sky-rocket, bringing new difficulties in financing.

Then in 1926, rubber prices fell as sharply, leaving again high-priced inventories to be absorbed and reducing profits.

Within the last three years, crude rubber has varied from 25 per cent to 65 per cent of the total manufacturing costs, a fact which tells its own story of the special financial difficulties which the industry has had to struggle with during the past six years.

The stronger companies, however, have been able to resume dividends on preferred stock and some on common, arrearages of cumulative dividends have been paid up and debts from the 1920 depression substantially reduced. Some of the smaller companies which carried small stocks were able to get through the period with little interruption of stockholder payments, and the general outlook for the future is for improved conditions.

The following list of the principal companies which publish their

annual sales (the figures being for 1926 in round numbers) shows rather strikingly how much of this industry has centered around the city of Akron.

Goodyear Tire and Rubber Co., Akron	$230,000,000
United States Rubber Co., New York City	215,000,000
B. F. Goodrich Co., Akron	148,000,000
Firestone Tire and Rubber Co., Akron	144,000,000
Fisk Rubber Co., Chicopee Falls, Mass.	68,000,000
Miller Rubber Co., Akron	42,000,000
Hood Rubber Co., Watertown, Mass.	40,000,000
General Tire Co., Akron	20,000,000
Seiberling Rubber Co., Akron	15,000,000
Mason Tire and Rubber Co., Kent	14,000,000
Lee Tire and Rubber Co., Conshohocken, Pa.	12,000,000
Mohawk Rubber Co., Akron	6,000,000
India Tire and Rubber Co., Akron	6,000,000

Labor. Although efforts have been made at various times to organize a rubber worker's union, the industry generally is open shop. There are several reasons for this. One is that working in rubber isn't a trade to be slowly acquired over a period of years like that of the printer or the machinist. It is highly subdivided into operations and officially classed as semi-skilled labor. While certain operations, such as calendering rubber into fabric and others require skill, judgment, and a considerable period to learn, most of the operations can be learned by a man of good aptitude and physique in anywhere from a few days to three weeks. In compounding, milling, and tire building and the like, men work to exact and explicit specifications.

The rubber industry had to train literally hundreds of thousands of men in one or another of its many operations from 1914 on. The industry was expanding at high speed, and during the War and post-war days, the supply of men fell continuously short of the need for them. Taking Akron as a typical example. That city increased in population in the decade 1910–20 from 69,000 to 206,000, largely due to the expansion of the many rubber factories there. The neighborhood labor supply was early exhausted, as was that from the surrounding towns. Farming districts of Ohio, Pennsylvania, West Virginia, Kentucky, Tennessee, and throughout the South furnished men to the rubber factories.

The requirements of the factories outran the physical capacity of the town adequately to house so large a number of newcomers. At the peak, men were living in rooming houses and even in tents, and

were often sleeping two shifts to a bed. Street-car service and other public utilities could not be enlarged fast enough to take care of the growing needs. Akron during that period was predominantly a city of single men or men whose families lived elsewhere. Evidence of this was the fact that though only the fifth city in the state in population, Akron sent more men into the National Army through the draft than any other city in Ohio except Cleveland, exceeding the larger cities of Toledo, Columbus, and Cincinnati.

While there is a high degree of stability among employees who had been in the factories long enough to find themselves, the difficulty which newcomers had in 1914–20 was well reflected in a magazine article printed during that period under the title " Akron Standing Room Only." This situation, with the general restlessness of the times made for a heavy labor turn over, offered serious obstacles to unionization, and compelled further subdivisions of tasks, so that any one operation could be quickly learned by a newcomer.

Again the rubber industry has always paid liberal wages and the manufacturers have gone to great lengths to improve working and living conditions. Figures computed by the National Industrial Conference Board, weighted as to number of weeks worked per year, show that average weekly earnings in the rubber industry went from $12.28 to $30.03 from 1914 to 1926, an increase of 245 per cent, while in manufacturing as a whole, taking 25 leading industries, the increase was from $12.54 to $27.27 or 217 per cent. Wages in the rubber industry reached their height in the third quarter of 1920, just prior to the depression, at $29.57, as a weighted weekly average. They fell as low as $23.07 in 1921, but gradually recovered, until in 1926 they were higher than they had ever been, being not only above the pre-war level, but above the highest post-war figure.

Two of the leading rubber companies, Goodyear and United States, have employee representation plans, under which the workmen elect representatives to deal with the management on matters of wages, working conditions, and the like. Employee representation has been an important factor in maintaining satisfactory working conditions, since these not only go into matters affecting employees as a whole, but those affecting only a single department, a group within a department.

Among the steps taken by the manufacturers in the Akron Dis-

trict to improve living conditions for employees were housing projects in which the factory men could buy their own homes out of their wages, educational programs, and athletics. Labor departments were set up not only to keep a more accurate record of employment and to supervise hiring, but as well to find and remove causes of difficulty in working conditions and to assist newcomers in getting located. The 1920 depression automatically solved the housing problem and, in the years since, good wages and immediate access to the management through foremen, the labor department, and the shop representative have combined to bring about a favorable working environment.

This Table Shows the Shift from Wild Rubber to Plantation Rubber.

Year	Plantations (tons)	Brazil (tons)	Other (tons)
1900	4	26,750	27,136
1914	71,380	37,000	12,000
1915	107,867	37,220	13,615
1916	152,650	36,500	12,448
1917	213,070	39,370	13,258
1918	255,950	30,700	9,929
1919	285,225	34,285	7,350
1920	304,816	30,790	8,125
1921	271,233	19,837	2,890
1922	354,980	21,755	3,205
1923	384,771	22,580	5,420
1924	391,607	23,514	6,096

CHAPTER XIX

THE WATER POWER INDUSTRY

By Frederick Darlington [1]

There is no record of the time and conditions of the first use of moving water as a source of power. Water wheels were known to the Egyptians and Babylonians and for many centuries were the chief source of mechanical energy.

The early wheels were made in three different types — undershot wheels for low heads, breast wheels for moderate heads, and overshot wheels for (relatively) high heads. They were crude in construction, slow in speed, low in efficiency, and greatly limited both in power and in adaptability to variations in the water supply and in the load. Yet, as they could grind grain more cheaply than any other known means, they were essential to early civilization, and towns sprang up wherever they were installed.

To the Americans of colonial times, water powers were looked upon as public necessities, essential for the common welfare, and in at least one colony a law was in force whereby an owner of an undeveloped water power could not hold his title against purchase for development for grist-mill use. Such a law governed the acquisition and development of water powers by public utilities in Virginia until comparatively recent times, and it is said this old law met modern conditions of eminent domain in water power quite well.

Though the old forms of wheels were exceedingly wasteful of both the available water supply and the energy in the water actually utilized, they remained without substantial improvement until 1827, when Bernoit Fourneyron, of France, invented a new type of wheel, called the hydraulic turbine, which eliminated a very considerable percentage of the losses of the older types.

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With this invention, modern water-power development may be said to have its beginning.

The hydraulic turbine was introduced in an improved form into the United States by J. B. Francis in 1849, and because of its superior speed and power, it quickly displaced the older wheels. It was, however, limited to heads of about 20 feet or less, and when higher heads were used, a series of canals at different levels was constructed.

Shortly after 1900, wheels were improved so that heads of 100 feet could be used directly, and by 1910 American manufacturers were building turbines for heads of 500 feet and upwards. For heads of 800 feet and higher, a different type of wheel is employed; namely, the Pelton impulse wheel, which was developed in California about 1888.

Prior to 1910, the multiple-runner turbine, that is, several wheels mounted on one horizontal shaft, was generally employed for large, high-head installations, but since then single-runner wheels on vertical shafts have been the accepted practice. This has been made possible by improved thrust bearings to carry the tremendous weight of wheel, generator, and water pressure.

In modern hydro-electric power plants, the conversion of over 90 per cent of the energy of the falling water into mechanical energy has been accomplished. Among modern turbines of notable design are wheels of 14 feet 11 inches in diameter, at Niagara Falls, which develop 70,000 horsepower, each on heads of 214 feet; and 17 feet 11 inch wheels at Cedar Rapids, which develop 10,800 horsepower, each at heads of 30 feet. Still larger turbines are under construction, including some with wheels 19 feet in diameter for use at Conowingo, on the Susquehanna River. Impulse turbines of the Pelton type are in use with heads of upwards of 2000 feet. In the design and construction of water wheels, American manufacturers lead the world.

Water-Power Developments Related to Developments in Other Industries. Along with water-wheel improvements, parallel advances have been made in other closely related and interdependent industries, so that progress in the water-power industries is largely progress in the part it plays in a combined service. This is especially true with respect to the electric-power industry. In the large modern electric-power systems, water powers, steam turbines, and other prime movers are combined, and each source of

power is employed in its best use in conjunction with and as a supplement to the other sources. In this way, water powers reach their widest and best use.

Such large systems have come to be known as super-power systems. They are so interconnected that various sources of power supply vast areas from unified systems, the growth of which by interconnection and new construction has been most rapid since the World War and is still going forward with increasing strides, constantly adding to the capacity of generating stations and transmission lines between major points of generation and consumption. For instance, with some rather slender but nevertheless important links, continuous power lines have been installed between Chicago and Boston, between Canada and the Southeastern States, and power shortages in important points have frequently been relieved by relaying power from points hundreds of miles away. For example, during a period of protracted draught, power in the Eastern Carolinas was supplemented by generating capacity in Western Alabama. In an emergency in Providence, R. I., the shortage was relieved by service from Northeastern New York State. Instances of such accomplishments might be multiplied and opportunities for power relay are growing with every improvement in main-circuit transmission line constructed.

Present statistics indicate 50,500,000 circuit miles of electric transmission lines in the United States on January 1 of this year. These lines join vast aggregations of electricity consumers to water powers and steam-generating plants and are the means by which hydro powers are able, at all times, to deliver the output of their generators to power users, thus continuously affording a useful outlet for water powers.

Classes of Water Powers. There is a wide variation in water powers, according to the nature of the water flow by which they are actuated and the use to which they are put. There are broadly three types of rivers: uniform-flow rivers, variable-flow rivers, and artificially regulated rivers.

Rivers of substantially uniform flow are rare in occurrence, but are particularly favorable for steady and enduring powers. Typical of this type, and almost the only rivers preëminently of this character in the United States, are the Niagara and St. Lawrence rivers on the international boundary of New York. Their flow, in a large measure equalized by the Great Lakes and in the Niagara

River, varies from a mean flow of 205,000 cubic feet per second to 176,000 cubic feet at low water.

Through the entire length of these rivers, from the Great Lakes to tidewater, there is an opportunity for the ultimate development of upwards of 11,000,000 continuous electric horsepower. This power, a large portion of which belongs to Canada, is striking in its magnitude as well as almost unique in its constant-flow characteristics, and in passing it is interesting to note that the energy capable of production with full development of the St. Lawrence and Niagara rivers, if made by steam, would require an annual consumption of about 35,000,000 tons of coal per year, or about 80 carloads every hour.

By far the larger part of the water power of the country, developed and undeveloped, is on rivers of variable flow. The range is exceedingly wide; the ratio from minimum flow to maximum flood often being in the ratio of 1 to 4000.

The best use of this class of power offers many difficult and perplexing problems, involving the coördination of water and steam powers and the regulation of rivers by storage reservoirs for improved water transportation, irrigation, and other lines of economic progress. For these things, water powers are most valuable supplements and in turn supplement the other industries. Notable instances of this will be referred to later on in connection with projects for navigation on the Tennessee River and Great Lakes–Tidewater navigation via the St. Lawrence and Niagara rivers, the Colorado River project, etc.

In view of the wide fluctuation in rivers under natural-flow conditions, much water is lost during flood periods which cannot be utilized for power purposes. In fact, it would be utterly extravagant and impracticable to install hydro-electric machinery for turning flood waters of short duration into power; on the other hand, during the periods of extreme low water, there are times when much hydro-electric machinery is idle for lack of water. In many instances, this may be equalized in a large measure by storage reservoirs to catch and retain flood waters and discharge them gradually through regulating gates during periods of insufficient flow.

A few rivers have already been materially improved by such regulating reservoirs constructed for power or for flood prevention or for irrigating water or for these purposes jointly, all of which

are helped by storage regulation, but much still remains to be done in this general line of work. Some rivers are fed by natural lakes, so that rather simple regulating gates at the outlets can aid materially to govern flood discharge and increase the minimum flow. Comprehensive statistics on this are not available for the country as a whole; in fact, only one river, the Tennessee, is being completely surveyed in this respect to give information concerning the Muscle Shoals–Wilson Dam power and navigation development. The War Department engineers, in conjunction with the United States Geological Survey, have stated, in a preliminary report, that over two million horsepower may be developed in the Tennessee River system with proper regulation (exclusive of Muscle Shoals). These strikingly important results have encouraged the belief that the Federal Government should extend their study of storage regulation to other important rivers throughout the country.

The value of storage on any given river increases as the water powers are developed along the river below the reservoirs. For example, about 1914, a large water power was installed on the Coosa River at Lock #12, Alabama. The head of this development was approximately 70 feet. Since then, an additional development has been made at Mitchell Dam and a further development is in process at Lock #18, and other developments will undoubtedly be made later on along this same river. Obviously such storage as may later be created at the headwaters of this river will be useful in reducing the flood flow and increasing the minimum flow at each power development, thereby multiplying the value of the regulation by storage.

There is still another form of storage which, though far more limited in the quantity of water retained and local in its application to individual plants, is nevertheless of importance to water powers. This is the regulation of river flow that is secured by much smaller local ponds or reservoirs that usually are part of each individual water-power development. For instance, on the Coosa River, just used as an example, the head for each of the developments is augmented by a dam which creates a pond running back a few miles up the river. These ponds, while not large enough to be important factors in controlling the discharge for a great flood or in long maintaining an important supplement to the low-water river stages, nevertheless are sufficient in size to permit daily regulation of the discharge through the water wheels, so that during

low-river stages, the energy can be taken from the plants during the daytime periods when there is the maximum use for power in industry and the water conserved at night when there is less demand for power. This is of vital importance since every power system in public service has wide variations between the daytime requirements and the late night and early morning demands. This ratio is ordinarily in the proportion of 4 or 5 to 1; that is to say, the night load is usually about one fourth as much as the day load.

Ponds created by local dams are used to control the discharge through the water wheels to coincide with the daily fluctuations in load and secure the maximum use and value to the energy of the water. Here again interconnected systems come into play to transmit this equalization into favorable combination with steam-generating plants and other hydro-electric plants.

Developed Water Power in the United States. In view of the wide variations in the flow of rivers, described in the foregoing, statistical figures on water powers are necessarily based on arbitrarily assumed ratios of stream flow and duration. Figures by the United States Geological Survey, which will be quoted hereafter, are made up as follows;

The amount of power that is available 90 per cent of the time.

The amount of power that is available 50 per cent of the time.

The figures given, of course, are averages and there are occasional times on the various streams when the minimum of power falls below the amount that is available for 90 per cent of the time, though the 90 per cent figure, in most instances, approaches the low value.

The Geological Survey, Department of the Interior, in commenting upon the capacity that may hereafter be installed at undeveloped potential powers, states that,

"Studies of the installed capacity at fully developed water-power sites indicate that in general the ultimate capacity of water wheels that may be installed at any power site will average about 130 per cent of the potential power available 50 per cent of the time."

The Department of the Interior, through the Geological Survey, reports that the developed water power of the United States in plants of 100 horsepower or more was 11,721,000 horsepower on January 1, 1927, an increase of 544,000 horsepower, or about 5 per cent during 1926. The figures for several recent years, as determined by the Geological Survey, are as follows:

1921	November . . .	7,926,958	1926	January 1 . . .	11,176,596
1924	March	9,086,958	1927	January 1 . . .	11,720,938
1925	March	10,037,655			

The developed water power in the United States in 1925 (plants of 100 horsepower and more) and the geographical distribution of the installed capacity by sections as given by the United States Geological Survey are as follows:

Developed Water Power in the United States in 1925

(Plants of 100 horsepower or more)

Division and State	Total		Public Utility and Municipal		Manufacturing and Miscellaneous	
	Number of Plants	Capacity in Horse-Power	Number of Plants	Capacity in Horse-Power	Number of Plants	Capacity in Horse-Power
United States		10,037,655		8,287,332		1,750,323
New England . . .	1,230	1,398,803	251	656,270	979	742,533
Middle Atlantic . . .	611	1,948,449	402	1,624,316	209	324,133
East North Central .	346	884,760	5	661,445	121	223,315
West North Central .	194	514,753	127	414,692	67	100,061
South Atlantic . . .		1,589,304		1,352,478		236,826
East South Central .	53	396,791	38	379,683	15	17,108
West South Central .	29	31,317	14	27,105	15	4,212
Mountain	234	937,078	185	915,737	49	21,341
Pacific	299	2,336,400	244	2,255,606	55	80,794

The annual production of electricity by steam and water power by public-utility plants in the United States for the years from 1919 to 1925 inclusive was as tabulated on the following page.

The annual consumption of coal and its equivalent in other fuels (oils and gas) in the production of electricity in public-utility plants in the United States during 1925 was 44,780,000 net tons. The average consumption of coal or its equivalent per kilowatt-hour by public-utility fuel-operated plants during the same period was 2.1 lbs., a reduction from an average of 3.0 lbs. in 1920.

The figures show that about one third of the kilowatt-hours generated by public-utility power plants of the country are by water power; totaled for 1925, 22,356,000,000 kilowatt-hours. Figured on the fuel consumed in the steam plants per kilowatt-hour for 1925 2.1 lbs. per kilowatt-hour generated, the use of water powers in public-utility service in the United States made a saving in 1925 of 23,000,000 net tons of coal.

Annual Production of Electricity by Utility Power Plants in the United States, 1919–1925

Year	Total		Water Power		Fuel Power			
	Kilowatt-hours	Change from previous yr. (%)	Kilowatt-hours	Per Cent of total	Change from previous yr. (%)	Kilowatt-hours	Per Cent of total	Change from previous yr. (%)
1919	38,921,000,000		14,606,000,000	37.5		24,315,000,000	62.5	
1920	43,555,000,000	+ 11.9	16,150,000,000	37.1	+ 10.6	27,405,000,000	62.9	+ 12.7
1921	40,976,000,000	− 5.9	4,971,000,000	36.5	− 7.3	26,005,000,000	63.5	− 5.1
1922	47,659,000,000	+ 16.3	17,206,000,000	36.1	+ 14.9	30,453,000,000	63.9	+ 17.1
1923	55,674,000,000	+ 16.8	19,348,000,000	34.8	+ 12.4	36,327,000,000	65.2	+ 19.3
1924	59,014,000,000	+ 6.0	19,969,000,000	33.8	+ 3.2	39,044,000,000	66.2	+ 7.5
1925	65,870,000,000	+ 11.6	22,356,000,000	33.9	+ 11.9	43,514,000,000	66.1	+ 11.4

The following table, taken from the August 21, 1924, table prepared by the Geological Survey, gives the water-power resources of the United States for the total country and by groups of states. The table employs the government standard method of rating rivers:

Potential Water-Power Resources of the United States

(United States Geological Survey Report, dated 8/21/25)

State and Division	Available 90 Per Cent of the Time		Available 50 Per Cent of the Time	
	Horsepower	Per Cent	Horsepower	Per Cent
United States . . .	34,818,000	100.00	55,030,000	100.00
New England . . .	998,000	2.87	1,978,000	3.60
Middle Atlantic . .	4,317,000	12.40	5,688,000	10.35
East North Central .	737,000	2.12	1,391,000	2.53
West North Central	871,000	2.50	1,844,000	3.35
South Atlantic . .	2,476,000	7.11	4,464,000	8.11
East South Central .	1,011,000	2.90	2,004,000	3.64
West South Central	434,000	1.25	888,000	1.61
Mountain	10,736,000	30.83	15,513,000	28.19
Pacific	13,238,000	38.02	21,260,000	38.63

From these figures it is noted that;

The total potential water power of the country available 90 per cent of the time is 34,818,000 horsepower and available 50 per cent of the time 55,030,000 horsepower. If the present ratio of capacity of plant to power available were to be continued until the total water-power resources of the country are utilized, the aggregate capacity of installed water wheels would be about 72,000,000 horsepower, or about six times the present installed capacity in plants of 100 horsepower or more.

These figures have been made up for the streams under their condition of natural flow without extensive storage regulating reservoirs to reduce flood losses and maintain increased power during periods of drought.

It is impossible to make figures as to how much power will be gained by storage regulation of rivers. Any such estimate at present would be unreliable, for comprehensive data is lacking and conditions vary greatly throughout different parts of the country. The only thorough study that is being officially made on this subject is the report, already referred to, on the Tennessee River.

Laws Governing Water-Power Developments: Federal Power Commission. The older water-power developments were made on lands acquired by private purchase of water-power sites, flowage lands, etc., or were acquired by condemnation under state laws of eminent domain. In some parts of the country, particularly in the West, many of the most valuable water powers are on public lands, forest reserves, national parks, etc., and prior to 1923 congressional action was necessary to secure titles for development of these sites. This often led to opposition and delayed hydro-electric construction. There was much public sentiment against granting Federal lands for power purposes, and Congress finally took action and passed the Federal Water Power Act, approved June 10, 1920, and amended March 3, 1921, establishing a Commission known as the "Federal Power Commission," whose purpose is briefly "to provide for the improvement of navigation, the development of water power, and the use of the lands of the United States in relation thereto."

This Commission consists of the Secretaries of War, Interior, and Agriculture. They organized for the purpose of issuing licenses under the terms of the Act to individuals, organizations, municipalities, or states, for the construction and operation of power developments upon navigable waters of the United States, public lands, and reservations and to utilize the surplus water from any Government dam.

Under the procedure set up by this Commission, individuals or corporations complying with specified requirements are granted preliminary permits for investigation and preliminary work towards power development and, upon compliance with the Commission's rules, these permits may be followed by permanent licenses issued for a period not exceeding fifty years, with a recapture clause and other conditions that have been found workable and which have led to extensive development and plans for still further development of a large amount of water power.

The Sixth Annual Report of the Federal Power Commission for the fiscal year ended June 30, 1926, reports:

"The Commission has issued a total of 389 permits or licenses. For major projects 137 permits and licenses were issued with an aggregate of 10,100,000 horsepower, 136 major applications with a total of of 14,690,000 horsepower still await action."

Dam Construction — Essential to Hydraulic Progress. The building of dams commenced before recorded history; in fact, cer-

tain water animals, notably beavers, possess uncanny skill in dam construction.

The earliest dams of history were used for irrigation and were in India, Egypt, and the Far East.

Modern storage reservoirs, created by dams in connection with irrigation, power generation, water supply, navigation, flood prevention, and sanitation, greatly enhance the value of the rivers by holding back and controlling flood waters.

Future hydraulic development will deal largely with water conservation by such storage and flow regulation. In fact, when water-storage possibilities are evaluated, present estimates of water power and other hydraulic works will be tremendously increased, greatly raising the figures for the nation's potential resources of undeveloped water power. When all the uses of water are considered, an acre of water will be more valuable than an acre of land.

The following are some of the notable dams of America made by earth and rock fills with or without core walls.

Bell Fourche Earth Fill, South Dakota, 122 ft. high and 6394 ft. long; impounds 66,500,000,000 gallons.
Gatum Dam, Canal Zone, 115 ft. high and 7700 ft. long.
Lahontan Dam, Nevada, 124 ft. high and 1300 ft. long.
San Leandro Dam, California, 125 ft. high and 500 ft. long.
Tabeand Dam, California, 120 ft. high and 630 ft. long.
Arrowhead Dam, California, 222 ft. high and 850 ft. long.
Calvers Dam, California, 240 ft. high and 1260 ft. long. Built 1913–1916 — the highest earth dam in the world.

Timber or crib dams, constructed of logs with earth and rock fill, are a modified form of earth construction but are mostly used for low heads or for temporary work. They were in common use in the early days when water wheels were practically limited to heads not exceeding 20 ft. or thereabouts, but have been generally superseded by later designs.

The extensive use of hydraulic cement concrete has promoted three distinct types of concrete dam construction:

A. Gravity dams, in which the mass and weight of mason work, resting on a suitable foundation, withstand the water pressure.

B. Arch dams, in which a curved masonry structure is built between abutments to resist water pressure on the principle of the arch. Where conditions are favorable, this permits a material saving in the yardage of concrete as compared with gravity section dams.

For years there has been a hotly contested discussion among engineers as to the correct principles to be applied in the design of arch dams. This is in process of being decided by a test arch dam built under Government supervision on a California river with the purpose of loading it to destruction and carefully observing every detail of its failure.

C. The third type of dam is of hollow construction with decks opposing the water resting on buttresses and weighted down by water pressure. They have been known as the "Amberson" dams and are still sometimes given preference where concrete materials are scarce or where they are particularly favorable for the foundation conditions.

Many other features of dam construction have been studied in minute detail, including spillways designed to secure against damage by the overflow and waste waters; movable crests that can be moved to ease the passage of floods and prevent damage by excessive back waters; flood-water discharge ways to create a velocity wave in the discharge to lessen the tailwater rise during floods. The "Thurlow Back Water Suppressor," named after the designer, Mr. O. G. Thurlow, and installed in the Coosa River Plant of the Alabama Power Company, is a striking application of this latter principle.

It is obvious that dependable concrete masonry is of paramount importance for building dams, and the rapid progress of recent years in cement making and concrete mixing and placing has contributed largely to successful and economical dam construction.

The following are a few notable examples of concrete or stone masonry dams:

Ashokan Dam, New York City Water Supply; 251 ft. high and 1000 ft. long.

Roosevelt arch type dam in Arizona, 260 ft. high and 680 ft. long.

Lake Cheesman arch dam, Denver Water Supply, 225 ft. high and 700 ft. long.

Arrowrock Dam, Boise River, Idaho, 351 ft. high and 1160 ft. long.

Elephant Butte Dam, Rio Grande River, New Mexico, 305 ft. high and 1310 ft. long.

Keokuk Dam, Mississippi River, 53 ft. high and 4649 feet long.

Barcelone Dam, Spain, the largest dam in Europe, built by American engineers. 330 ft. maximum height and 700 ft. long.

Interconnected Electric Systems. Electric power generation and transmission is first in importance of all the many factors contributing to increased use of the energy of falling water. Prior to 1900, electric power in the United States was less than 5 per cent of the total — 500,000 horsepower out of 11,000,000 horsepower total combined water and steam power. Without electric transmission, power had to be used where it was generated, which, in the case of hydraulic plants, was at the falls of the rivers, where factories were grouped, and to this grouping all other considerations, such as sources of raw materials, transportation, accessibility, labor market, etc., had to be subservient.

Fluctuations in power, due to high- and low-water stages, cause changes in the amount of power available, and mills that operated in daytime only often required little if any power at night, when much power went to waste. On the other hand, there were periods of drought when the powers were inadequate for normal daytime needs, and the "use factor," as it came to be called, of the water powers was very low, meaning that the ratio of their average use to their installed capacity was unsatisfactory. In many cases their low-water capacity was supplemented by steam plants, and these plants in turn were idle for long periods when water was abundant. Still further, if a business depression occurred, leaving the mills temporarily idle for lack of orders, both the hydraulic plants and the supplementary steam plants were of necessity idle. All of this has been changed by the general substitution of electric power generation and distribution, replacing direct mechanical drives from water powers. This substitution of electric drive for mechanical has become nearly universal, particularly in the case of hydro plants, the older hydro plants having been converted to electric generation, and practically all the newer plants are so constructed.

Load Factors. In the multitudinous uses to which power is put there is a wide range in the hours it is employed per day or per month. For domestic purposes — heating, small motors, lighting, etc. — each piece of apparatus consumes power only a small part of each day or month. Lights are on at night, and not so much in summer as in winter; fan motors operate chiefly in hot weather; elevator motors, vacuum cleaners, battery charging sets, electric irons, in fact, a great line of service uses of electric energy, are most intermittent. When it comes to the larger uses of power in manufacturing plants, machine shops, textile mills, foundries, street

railways, etc., there is a much longer average use of power; but even in these it is mostly used in the daytime with relatively little use during late night or early morning hours.

Other industries consume power for much longer periods. These include steel mills, wood-pulp grinding plants, steam railroads, and certain chemical plants. Some run day and night, but of all the various power applications none are coincident in the time of their greatest demand, and electric systems have grown up in which the vast variety of consumers are supplied from interconnected electric lines, to the end that the maximum power for the entire service is only enough to meet the simultaneous joint need of the various consumers that happen to be taking power at one time. This is always far less than the sum of the maximum requirement of each customer. With large interconnected systems generating capacity is enough to take care of fluctuations of individual consumers without appreciable fluctuation in the entire system, and although the system load slowly changes from hour to hour, the system's maximum is always far less than the sum of the consumer's maximum demands. When combined, the night loads, even though they are less than the day loads, make an aggregate demand for night power that never goes completely off. The night load of interconnected systems is ordinarily from one fifth to one third of the daytime load, and since there is always some load, there is never a time when water power cannot be used in such systems.

There is still another way in which these great interconnected systems enhance the value of water powers. They provide a use at all times for the variable output due to high and low water for the entire range of production, and the difference between the hydro-electric power available and the power requirements is made up by steam-turbine plants feeding into the system.

As the area covered by interconnected electric systems is increased, the system loads become larger and larger and a quarter of a million or more kilowatts in one system supplied from generators of 20,000 to 50,000 kilowatts or more each, with hundreds of miles of interconnecting lines, is now common practice. Such systems have come to be commonly called "superpower systems."

These systems, with water and steam power supplementing each other, lend themselves particularly well to further equalization and enhanced use of hydro-electric power by storage reservoirs, since in such systems the power from stored waters can always be drawn

upon when it is most needed to carry heavy system peak loads and relieve the demand on the steam plants. Power from stored waters that can be used when and as needed is greatly superior in value to power that can be generated only at the time of unregulated river flow, which seldom corresponds to the time of greatest need. Storage reservoirs, therefore, are used to control "fugitive waters," as they are called, to equalize stream flow for the joint improvement of power generation, navigation, irrigation, water supply, sanitation, etc., all of which services are assuming increasing importance, thereby greatly enhancing the value of water powers.

Distribution of Water Power in the United States. The geographical distribution of potential water powers in the United States is most uneven, as shown by the table of potential water powers on page 603, which is a Government estimate by districts. This table will be subjected to important changes as hydro-electric development proceeds and more complete information is secured and as storage reservoirs are constructed to regulate the rivers.

The outstanding features indicated by this table are large hydro-electric powers for certain sections including particularly the Northwestern states, New England and New York State, the Southeastern states of Alabama, Georgia, Tennessee, and the Carolinas, and very small hydro-powers in the South Central states.

These groupings will necessarily exert a strong influence on the development and location of power-consuming industries. With only about one sixth of the potential hydro-power at present developed, certain sections are even now looked upon as especially favorable manufacturing locations. For example, New England was early a leader in textile works, with water-driven mills at Holyoke, Lawrence, Lowell, Manchester, Lewiston, and other places. Later there was a movement in textile work to the Southeastern states, influenced by favorable water powers and raw materials.

As interconnected systems extend, the advantages of water power are more and more distributed over large areas. For example, in New England, it is no longer necessary to locate mills at falls on rivers to get the benefit of hydro-power. With this restriction removed, factories may be remote from water-power sites to suit conditions of labor, housing, transportation, raw materials, sanitation, thereby extending the opportunity to use hydro-power and, it is believed, establishing conditions that will aid in the decen-

tralization of population; *i.e.*, reduce the proportion of inhabitants who live in large cities as compared with village population.

Capital Costs and Operating Expenses of Steam Power and Water Power Contrasted: Military Preparedness, etc. Much has been written and said about coal conservation by water power. "Use white coal and conserve fuel" has become a slogan among conservationists.

Central-station power systems in the United States, exclusive of power produced by isolated plants and railroad locomotives, generated for 1926 (estimated from ten months' operation) (see "Electrical World," January 1, 1927) 68,732,000,000 kilowatt-hours, of which 25,132,000 kilowatt-hours, or a little over one third, was generated by hydro-plants, the remainder being by fuel-operated plants, which consumed on an average 2.1 lbs. of coal per kilowatt-hour. On this basis, the hydro plants in the central-station electric systems are saving about 25,000,000 net tons of coal per year with the water power of the country only about one sixth developed, according to the Government figures.

There is another comparison between steam and water power that is of military importance and should be considered quite aside from purely economic and conservation standards as long as nations are called upon to provide military defenses. Steam plants require many more men for their operation, including mining and transportation of coal, than equivalent water powers do. This difference of operating labor is not measured by the relative cost of power by the two methods. Vast crews of men are needed to mine and transport the coal for steam plants, to fire boilers and operate generators and to maintain the plants. Hydro-electric plants, on the other hand, may be operated and maintained with minimum crews of men; but investment costs, and therefore capital charges, are just the reverse — that is, the invested capital is ordinarily much larger in water powers than in steam plants.

Bearing in mind that there are wide differences in individual cases, we submit the table at the top of the next page to give a comparison of the various major elements of production cost by large generating plants, steam and water, under conditions where the total cost of power by the two methods is about the same.

The operation of steam plants, as above, costs \$17.50 per kilowatt for labor or for materials that require labor expenditure to produce, while in the water-power plants, operation and maintenance labor

COST OF POWER PER KILOWATT PER YEAR

	For Steam Plants Costing $110 per Kilowatt to Construct	For Water Powers Costing $240 per Kilowatt to Construct
Capital charges, taxes, depreciation and obsolescence @ 12 per cent	$13.20 per year	$28.80 per year
Operating and maintenance, labor and material except fuel	5.00	2.00
Fuel, say $4 per ton for 5000 hours per year, average use of plant capacity .	$12.50	
Total cost of power per kilowatt per year exclusive of transmission and distribution	30.70	30.80

amount to only about $2.00 per kilowatt per year, or about one ninth as much as in the steam plants. This ratio is of course only an average for an assumed condition. In practice it may go as low as one fifth, more or less, or as high as one twentieth, more or less.

This does not cause a difference in the total cost of power, for the labor ratio is partly or wholly offset by the higher capital cost of hydro plants, but the important fact remains that only about one ninth, more or less, as much labor is needed for producing hydro-power as for steam power including in the latter the mining and transportation of fuel, etc. Water powers would be a strong asset to any nation engaged in a war requiring its highest man power.

Terms and Abbreviations: Water Power. Water power is mechanical work derived from the energy of falling water. The machines by which this energy is converted into work are called "water wheels" or "hydraulic turbines."

If a given number of pounds of water (P) fall through a height (H) feet, the energy is $P \times H$ ft.-lbs.; thus if 1 cubic foot of water weighing 62.4 lbs. falls through 10 ft., the energy is 624 ft.-lbs.

Horsepower. One horsepower is 550 ft.-lbs. per second. The measure of horsepower in falling water is the product of the pounds falling per second times the feet of fall, called the head, divided by 550. Since a cubic foot of water weighs 62.4 lbs., the horsepower of falling water is the cubic feet of water falling per second times 62.4 times the height of fall in feet divided by 550. If CFS repre-

sents cubic feet of water per second and H represents the height of fall or head in feet, the theoretical horsepower (HP) of a water fall is

$$HP \text{ equals } \frac{CFS \times 62.4 \times H}{550} \text{ or } \frac{CFS \times H}{8.81}$$

Hydro-Electric Power. This term is used to designate electric energy that is produced by water-wheel-driven generators converting the mechanical power of the water into electric energy. Usually the moving part of the electric generator is mounted on the water-wheel shaft and the combined water motor and electric generator is called a "hydro-electric generator."

Kilowatt. The electrical energy output of generators is rated either in electrical horsepower (EHP), which is the equivalent of 550 ft.-lbs. per second of mechanical work, or it is rated in kilowatts (KW). One horsepower is equal to .746 kilowatt.

Horsepower-Hour or Kilowatt-Hour. A horsepower-hour (HPH) or a kilowatt-hour (KWH) is the energy of one HP or one KW for one hour.

Hydro-Electric Generator Efficiency. The efficiency of hydro-electric units is the ratio of the energy of the falling water into the equivalent electrical energy produced, and the amount that this is less than unity represents the loss in conversion by the water wheel from falling water to mechanical work and by the electric generator from mechanical work to electrical energy. Recent large hydro-electric generator tests report efficiency ratios in excess of .9 or more than 90 per cent overall efficiency, so that less than 10 per cent of the energy of the falling water is lost in the conversion to electric power.

This high efficiency is significant as showing there is no great margin for improvement in the output of modern waterpower plants.

Primary Power and Secondary or Second-Class Power. Primary power is power that, barring unforeseen accidents, is continuously available throughout every day, month, and year.

Power is called "secondary" or "second-class" when it is liable to interruption from occasional and foreseen recurring conditions. For example, from droughts, causing low water, or from floods, interfering with operation.

Part-Time Power. Power may be available only for part time and still be primary power, provided it is not subject to interruptions

from recurring disturbances. For example, primary power may be continuous twenty-four hours each day and every day or, again, primary power may be available only ten hours each day; provided it is available every day, it would still be primary power and as such is wholly acceptable for the operation of textile mills, machine shops, and industries that work on eight or ten hour per day runs.

Many water powers are operated on a much larger output for eight or ten hours a day than they could produce on a continuous twenty-four hour a day basis by allowing the water to accumulate in the forebays or dams during fourteen hours per day, more or less, when it is not needed, and drawing on these reservoirs during the working hours.

Load Factor. The load factor of a power plant is the ratio of the total output of the plant in kilowatt-hours or horsepower-hours, divided by the output that would have been generated if the plant had operated continuously at full capacity; thus, if a given plant produced only half as many kilowatt-hours in a year, or in a day, as would have been produced if the plant had run fully loaded continuously for the year or the day, it is said that the annual load factor or the daily load factor, as the case might be, was 50 per cent.

Some Notable Hydro-Electric Installations and Projects: Niagara Falls. The most noted power development in the world is undoubtedly that at Niagara Falls. Natural conditions here are almost ideal for power purposes. A large volume of water (225,000 cubic feet per second) flows from Lake Erie to Lake Ontario; this flow, as has already been pointed out, varies less than 15 per cent the year round, due to the regulating effect of the Great Lakes; and it drops through a total vertical distance of 325 feet within a horizontal distance of seven miles, 167 feet of the drop being at the Falls proper.

Were all the water of Niagara River at the total available head used for power purposes, about six million horsepower could be developed. By treaty agreement, however, only about 25 per cent (36,000 cubic feet per second for Canada and 20,000 cubic feet per second for the United States) can be diverted in order to prevent marring the beauty of the Falls. This apportionment may eventually be increased, since careful engineering estimates indicate that upwards of 50 per cent of the water can be utilized for power without injury to the Falls, and it is claimed that an improvement can be effected by reducing the flow over the Horse

Shoe Falls and taking steps to stop the disintegration of the crest at this point.

The first hydro-electric development at Niagara took place in 1895, when ten 5000-horsepower generators were installed on the American side. Other developments on both sides of the river followed, and in time over half a million horsepower was being generated.

The earliest installations utilized only the head at the Falls, so that only about half of the available power was being produced. Under modern methods, the water is being drawn from the river from a point above the Falls through canals and tunnels to the whirlpool, on the American side, and to Queenston, at the lower end of the gorge, on the Canadian side. When these developments are completed, all of the water legally divertible will be employed at a head of over 300 feet and under conditions of the highest efficiency, and a total of about 1,500,000 horsepower will be produced.

Muscle Shoals. The largest hydro-electric installation lying wholly within the boundaries of the United States is at the present time at Muscle Shoals on the Tennessee River in the northern part of Alabama.

This development was undertaken by the Government in 1918 during the World War primarily to provide a large volume of electric power for the manufacture of fixed nitrogen to be used for ammunition, and secondly, as a part of a general plan to make the Tennessee River navigable.

Wilson Dam, as the structure at Muscle Shoals is called, is a mile long to create 95 ft. head. Generators of a total capacity of 260,000 horsepower are now installed, and the ultimate capacity of the plant is 640,000 horsepower.

In marked contrast to the almost uniform Niagara River, the Tennessee is an exceedingly "flashy" stream. At times of flood over a million horsepower might be generated at Wilson Dam, while in times of drought the total may fall below 90,000 horsepower. It is evident from previous discussion that this highly variable power can only be economically used by connecting it into an extensive super-power system and using it to supplement other water power and steam plants.

St. Lawrence River. One of the proposals now being earnestly considered by the people of the United States and Canada is to

convert the ports on the Great Lakes into ocean ports by providing a 27-foot channel for the entire length of the St. Lawrence River.

The relation of power to this great navigation project has been well expressed by Herbert Hoover, Secretary of Commerce. "The final opening of this waterway from the Lakes-to-the-Sea," said Mr. Hoover, "has been the dream of many men for a generation, but its enormous cost seemed to overwhelm its economic values until invention brought to us a new resource. During the last fifteen years the perfection of long-distance transmission of electricity to the commercial markets has made possible a large recovery of the cost of these works through the sale of the 5,000,000 of horsepower which will fall over these dams. It comprises the largest single source of power and one of the most economical developments on the continent. It would take some years to absorb this volume of five millions of horsepower. But time moves swiftly in our industrial demands. In so short a time as fifteen years, we have increased our use of electrical power on the whole North American Continent from less than 17,000,000 horsepower until today we are using about 48,000,000 horsepower.

"Every time we apply these great forces of nature in the generation of power, we save the depletion of coal and the vast energy required to transport it. As we furnish power at less and less cost, and as we increase the volume of its supply, we increase the production of articles which go to make up our standards of comfort and we decrease the sweat of men and the drudgery of women."

Passamaquoddy Bay. Of great interest, especially to engineers, is the contemplated plan to develop power from the famous high tides which rush twice daily up into the Bay of Fundy.

Tidal power has been a subject of engineering speculation for many years. There is evidently a vast amount of power in the tides, but the problem of securing it economically under ordinary conditions has not as yet been solved. It is, of course, a simple matter so to locate generators that they will be turned when the tide comes in and when it goes out, but such power would be so variable as to be almost worthless.

But at Passamaquoddy Bay, on the border line between Maine and New Brunswick, and at the head of the Bay of Fundy, conditions exist which, in the judgment of engineers, make the development of tidal power feasible. Due to the configuration of this coast line and the existence of a number of advantageously placed islands,

it is possible by building five short dams to create two pools, one of 100 square miles and the other of 50 square miles in area, with a power house situated in between. When the tide, which rises about 15 feet at this point, is high, the water is admitted into the upper pool, and when the tide is low, it is allowed to flow out of the lower pool. In this manner, a difference in level can be established between the two pools, and a certain amount of water can be allowed to flow constantly from one pool to the other through the power house without reducing the difference in level below eight feet, — the minimum practical water-power head.

Owing to the immense size of the two pools, it is estimated by engineers that the permissible interpool flow would be sufficient to generate 500,000 horsepower. The governments of both the United States and Canada have authorized the undertaking, and at the present time preliminary engineering studies of it are actually under way.

Colorado River. Another hydro-electric project of first importance is being considered in connection with the Colorado River.

In Boulder Canyon — the last of the series of Colorado River canyons, of which the Grand Canyon is the best known — it is proposed to build a dam 700 feet high, which will control the floods that now frequently menace Southern California, permit the irrigation of hundreds of square miles of what is now desert, and produce upwards of 1,000,000 horsepower.

The engineering problems involved in this undertaking are relatively simple, but the interests of seven states — Wyoming, Colorado, Utah, California, New Mexico, Arizona, and Nevada — as well as those of the Federal Government and of Mexico, are involved.

Attempts to harmonize all of these interests have so far failed, and it is doubtful when an agreement which will meet unanimous approval will be framed.

CHAPTER XX

THE WOOL INDUSTRY

By MAX W. STOEHR[1]

A general idea of the extent of the wool textile industry may be obtained from the last Census of Manufactures prepared by the Department of Commerce. We find that "according to data collected at the biennial census of manufactures taken in 1926, the establishments engaged primarily in the manufacture of woolen goods and worsted goods reported, for 1925, products valued at $957,790,338.

"The total was made up as follows: Woven goods 579,788,935 square yards, valued at $673,569,023; yarn for sale, 150,999,907 pounds, valued at $210,692,105; miscellaneous products valued at $73,529,210. Of the total for woven goods, 304,683,747 square yards, valued at $308,124,413, were produced in woolen mills, and 275,105,188 square yards, valued at $365,444,610, in worsted mills."

The industry belongs not only to that class which is called "basic," but is of the greatest economic significance. This is further indicated by the fact that during 1925, 503 factories employed 67,056 workers; while 329 worsted mills employed 98,168 operatives.

A survey of the woolen industry shows that it has been subject to less geographical change in recent years than is the case with other textile manufactures; for, in 1869, 64 per cent of the mills were concentrated in New England, 35 per cent in the Central Atlantic states and 1 per cent in the remaining states. In 1919 New England had fallen off only one tenth of 1 per cent, the Central Atlantic states stood at 31.8 per cent, while the rest of the country contained 3.3 per cent of our woolen textile mills. In the above figures Vermont, which contained 17 mills in 1919, is not included.

[1] President Botany Consolidated Mills, Inc.

At the present time there is, however, a tendency for each geographical division to concentrate on certain types of product. In 1919 over 90 per cent of all the woolen suitings, over-coatings, and dress goods made in this country were turned out by the mills of New England and the Central Atlantic states; while blankets and woolen yarns and knitting seemed to be the chief productions of Minnesota, Tennessee, and Oregon.

If our estimate of the geographic distribution of this industry is to be based on the number of employees, we find that Massachusetts leads in both woolen and worsted manufactures; that Maine is second in woolen goods, with Pennsylvania third; while Rhode Island is second, Pennsylvania third, and New Jersey fourth in worsted goods. Manufacture of wool in the various types of cloth has been very largely dependent upon the changes in style demand and the supply of raw wool. The development of new machines to work different grades of fibers has also had its effect upon the industry.

Prior to the Civil War the Merino sheep were the most popular among breeders. After the war a wave of popularity for mutton in the meat market resulted in a switch to certain English breeds that combined good fleeces with a carcass of high food value displacing the Merino, the carcass of which is small and of poor food value. In this way the fine and medium-fine stock derived from the English animal began to supplant "the soft and superfine Merino combing wools." In 1870 the development of railroads and transportation facilities in the far West made available another supply of wool particularly suitable for the industry. The importations of wool from abroad, particularly in recent years from Australia and South Africa, have had their effect upon our market. The following table would show the proportion of foreign wool to the total quantity consumed in the United States from 1869 to 1919:

	1869	1879	1889	1899	1909	1919
Woolen Manufacture .	10.1	10.4	9.1	15.0	16.6	39.6
Worsted Manufacture .	22.4	38.1	38.8	31.8	38.8	46.1

Boston is, at the present time, the center of the country's wool market despite competition due to the shifting of our chief wool-

growing areas from the Ohio Valley to the mountain states of the West in recent years. Philadelphia and Chicago carry on an increasing amount of business in raw wool, while New York is of considerable importance in the carpet-wool market.

According to the National Association of Woolen Manufacturers the largest world's wool clip in a single year was in excess of 3,100,000,000 pounds just prior to the war. Prices have declined considerably during the last decade, but in 1926 were about 90 per cent in advance of 1913. The decreased value of the dollar has, however, more than compensated for this apparent increase.

A study of the relation between the size of the wool clip and wool prices from 1910 to 1926 has recently been compiled by the Harvard Economic Service. The following conclusions were reached:

"Examination of these figures reveals a very interesting illustration of the interplay between the production and the price of a commodity, the supply of which cannot be adjusted quickly to changes in demand. It takes a considerable period of time to build up the flocks of sheep to the size necessary to meet a greatly increased demand for wool; and when the demand for wool declines, it is usually not economical to reduce the size of the flocks suddenly. Under these conditions of supply the year-to-year changes in the size of the clip are likely to be very small while the price changes are very great, and the adjustments or production and price to each other are not made quickly. The largest clip during the period was only 19 per cent above the smallest, while the highest annual price was 210 per cent above the lowest. The disparity in range of fluctuations is not directly apparent from the charts; if the chart scales had been selected for the purpose of making this comparison, the apparent variations in the size of the clip would have been very much reduced."

Examination of the year-to-year movement of the two series shows the tardiness with which adjustments between production and price are made. Wool prices were comparatively low for five years, from 1910 to 1914, and only toward the latter part of this period did the size of the clip begin to decline. After two years of declining clip, prices started upward in 1915. The clip declined further, however, in 1915 and 1916, but increased in 1917, after prices had risen considerably for two years. Prices continued to rise in 1917 and 1918 and in the latter year reached the highest point during the period under review. The clip rose further in

1918, in response to war demands and high prices, and continued to increase in the three following years, reaching a peak in 1921 — a year of business depression and very low wool prices. A very sharp drop in the size of the clip occurred in 1922. Prices rose considerably in 1922 and 1923, and held at a high level in 1924 and 1925; but it was not until 1925 that the clip made an important increase. In 1926 it rose to a post-War record. As a result of these large increases in the clip, prices declined in 1926, but remained approximately 90 per cent above the average in 1913, when wool prices were at a low level. Present prices, though approximately 8 per cent below the 1926 average, are at a level high enough to insure a large volume of wool production, such as might well result in some further decline in wool prices.

Introduction of the Industry in the United States. The introduction of the industry into America dates from 1643, when a fulling[1] mill was erected at Rowley in the Massachusetts Bay Colony. In that year some twenty families from the cloth manufacturing section of Yorkshire, England, settled in the town and under the direction of William White, Robert Cushman, and Richard Masterson, who are supposed to have been wool carders, their products soon attracted the attention of the other colonists. The American Indians at that time had no knowledge of how woolen cloth might be made from wool, and it is said that the first domestic sheep in the United States continent were introduced at Jamestown, Va., in 1609.

During this early period, and indeed for many years afterwards, a large proportion of the sheep, as well as the machinery used, were imported from England where, of course, the industry was in a flourishing condition. There seems to have been no marked development in the process during the Colonial period, although a considerable number of small manufacturers appeared along the Atlantic seaboard.

How Woolen Cloth Is Made Today. In order to give a clear picture of how raw wool is transformed into fine fabrics today, it will be necessary to examine the process step by step. The prime factor in wool manufacture is the fact that wool fibers are covered with microscopic hooks which tend to mesh when the individual fibers are brought into contact with each other. The fleece is clipped from the sheep's back in one piece so that the different parts

[1] The process of shrinking cloth to the proper size and density.

may be readily sorted out. It is of interest to note that the Australian government lists 800 varieties of wool.

Breeds of sheep vary in the quality and quantity of wool which they produce. In this field there has been a marked advance in recent years through scientific breeding, so that a Merino-Lincoln sheep is expected to yield between 8 and 10 pounds annually. Of course, each type of cloth requires a different grade or grades of fleece, running from finest grades of the lightest fabrics to the coarse wool used in the manufacturing of carpets, the long, fine fleece being the most desirable.

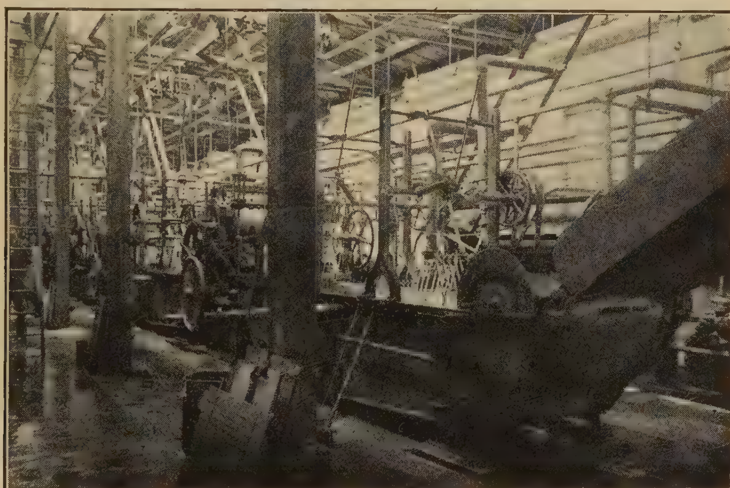

FIG. 1. — Wool washing.

The fleeces are received in large bales, from which they are transferred to the sorting room, where they are laid out on tables and skilled workers separate them into the several grades of wool which go to make up each fleece. The best portion is taken from the breast, shoulders and sides of the animal, the quality decreasing towards the tail. The wool on the belly is usually dirty and worn short, and consequently of a poorer grade. The fleece when clipped and sorted is very dirty, full of burrs, straw, and other foreign matter.

The grades of wool are placed in separate baskets, which are returned to special bins, each containing a single grade of fleece. Even in the case of sheep that are washed before clipping, it is

evident that the wool must be thoroughly scoured before it can be further handled. It is therefore put through long, narrow tanks filled with cleansing materials. A specially prepared potash soap is generally used, but naphtha is also employed in some processes. The wool is then thoroughly rinsed and dried. If there is a great deal of foreign matter remaining in the wool after scouring, such as burrs, seeds, etc., it must be carbonized; that is, treated chemically to reduce the vegetable matter to carbon in a bath of sulfuric acid or other chemical agent. This burns out the vegetable matter,

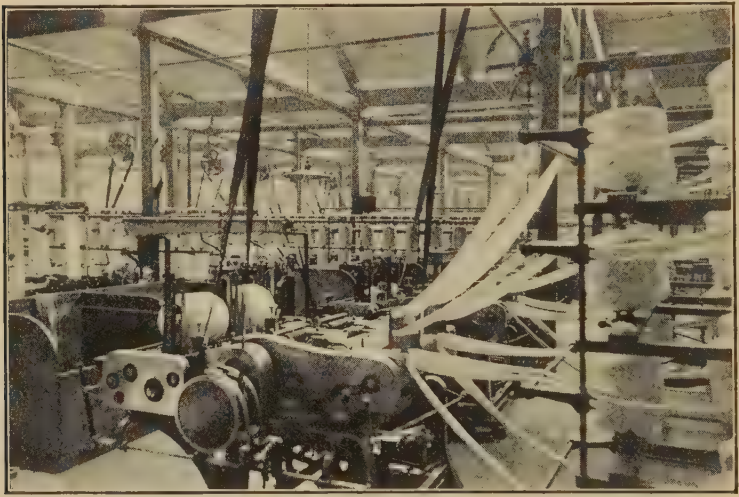

FIG. 2. — Drawing.

after which the wool goes through a neutralizing bath. It then passes through rotating combs to knock off any carbonized materials or foreign substances.

The blending of the types of wool to be converted into yarn is next made. In most processes it is necessary to oil the fleece before this is done. The best grade of olive oil is used, the lubricant serving to make the fibers more plastic and workable and prevent them from being thrown into the air during the carding process, which is one of the most interesting in the manufacture of yarn.

Its object is to pull out the wool fibers and combine them into narrow strands. The wool is passed between rollers that are covered with fine wire teeth known as "clothing,"[1] which mix the

[1] Wools so treated are known as "clothing wools."

fibers thoroughly. Before the fleece is properly carded it must pass through a number of these rollers, and when complete, the fibers cling together. The wool is taken off the machine in a flat strip, varying in width according to the purpose for which it is destined.

This strip in the woolen process is next spun and for worsted must be combed and drawn before spinning; processes which are exactly described by their names. The principle involved in spinning is a simple one, but the machinery required is very elabo-

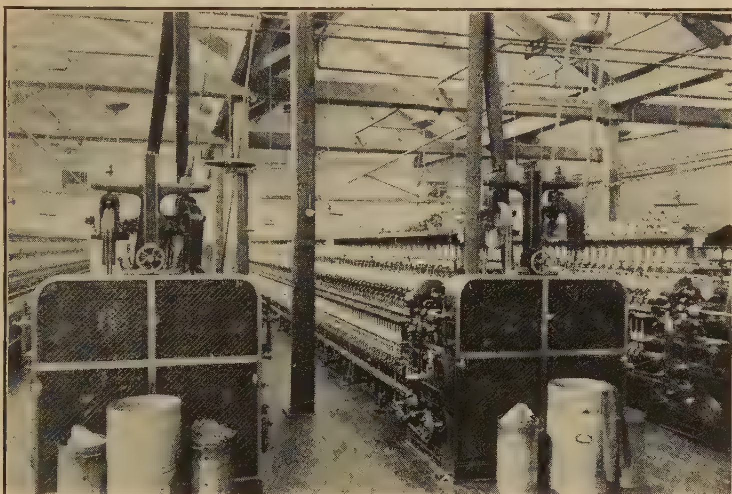

FIG. 3. — Throstle spinning.

rate. The woolen "mule," as it is called, is regarded by some engineers as the most ingenious of machines. The purpose is to twist these strips or slivers of fleece and draw them out so that they are converted into yarn suitable for weaving. Woolen "mules" are often made with several hundred spindles on which the thread is wound. These can be adjusted to meet varying requirements.

There are a few intermediary steps between spinning and weaving, particularly for the yarn that is to be used in the warp. This yarn must be wound and sized and put through the warping and "drawing in" processes. The first step is to wind it on small spools in order that it may be handled with ease. Then it is put through a bath of paste and water — a process called "dressing" or "sizing." This tends to smooth the yarn and to remove any

protruding fibers which might cause difficulty in weaving. A further effect is to strengthen this warp yarn, which is usually subjected to greater strain than the weft or filling. The last stages — the warping and drawing in — consist of winding the yarn upon the loom beam (a large spool which is placed behind the loom), the proper arrangement of the yarns in the warp according to the design required, and the drawing of the yarns through the harnesses. The final step is mounting the whole apparatus upon the loom. Everything is then ready for weaving.

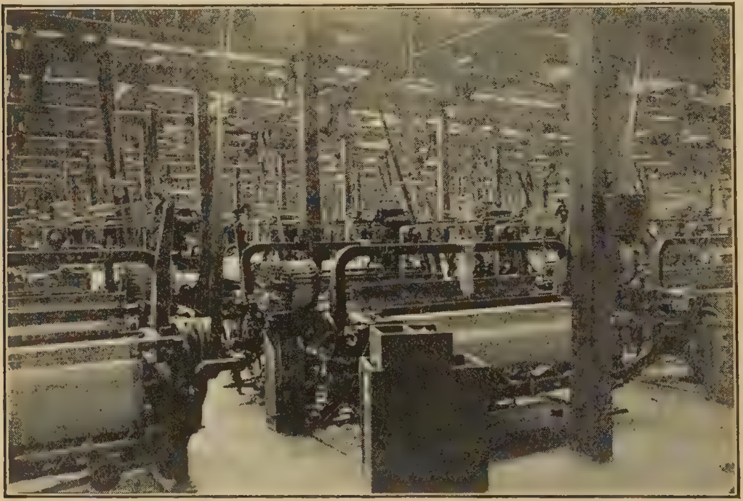

Fig. 4: — Weaving.

Weaving is another process which is simple in idea but elaborate in execution. Its object is to make vertical and horizontal threads mesh together in such a way as to form cloth. A great variety of looms have been designed, running from the simple apparatus employed by our forefathers to elaborate automatic mechanisms that weave fancy designs, so constructed that they relieve the weaver even of the responsibility of seeing that the shuttles contain yarn. These automatic looms are rapidly increasing in number in the American industry. It is not expected that they will be as satisfactory in the woolen manufacture as they have been in the cotton industry, chiefly because of the weakness of wool yarns, but there is without doubt a large field for them.

The next process in cloth making is the finishing. Weaving

constructs the fabric, but in reality woolen cloth is made in the finishing process. The cloth as it comes off the looms is often loosely hung together and sleazy in appearance, and a number of operations are required to make it a usable article. The first of these is scouring to remove the paste sizing from the warp yarns. If the yarns were not dyed in the skein (when a fabric may be termed " dyed in the wool "), it may be dyed at this point. Cloths so treated are called " piece dyed."

This is one of the picturesque steps in the making of cloth. The dye-house is usually a high room and well ventilated so that the steam arising from the dye vats may pass off as quickly as possible. It is necessary to keep the temperature at a fairly high level. In cheaper cloths using cotton warp, a process known as " cross-dyeing " is employed, in which the cotton is dyed in the yarn, and after the fabric is woven it is soaked in coloring materials of a chemical character which affect the wool but not the cotton fibers.

In some plants the cloth is carbonized at this point for the purpose of burning out any burrs or bits of vegetable matter that may have escaped detection up to this point. The next stage of the cloth's development is that it be shrunk to the proper density. This step is peculiar to woolen manufacturing since neither cotton nor silk responds in any marked degree to a shrinking process. The wool, however, is in this way " felted " or solidified to a firm, workable fabric. The process is carried on in long machines which immerse the fabric repeatedly until the desired result is achieved both as to the length and width of the cloth. It is then scoured in clean water so that the soap and any chemicals which have been employed are removed.

The next steps are known as " napping " and " shearing." The napping apparatus contains rollers covered with fine pointed wires, or a teasle, a special type of thistle grown in France and Spain. The cloth enters the machine a hard-surface fabric, but the teasles or wires are an abrasive that provide the material with a sufficient nap. Shearing is done by means of rotating knives that resemble a lawn mower. These revolve at a high rate of speed and clip off part of the nap so that it is reduced to a uniform length. The shearing is sometimes done independently of napping when a smooth surface is required. Brushing and pressing follow to give the material the final finish.

Among the many other processes which are essential to the making of cloth is that of " burling," which merely means that the fabrics before they reach the napping process are carefully examined for defects which are marked, and the material sent to another department for expert repair or mending.

There are many variants of the process herein described, depending on the type of goods to be made. Flannels, for example, are practically complete when they leave the loom, requiring only to be scoured, dyed, or bleached, inspected, mended, and pressed. " Face-finished " goods undergo a particularly elaborate process involving ten or fifteen operations.

Worsted Cloth Manufacturing. The operations required for the manufacture of worsted cloth are in some steps identical with that of woolen cloth manufacture. The carding process, for example, is approximately the same. The machinery involved has slight technical differences, however. The combing of worsted yarns is a most important process. The fibers of the worsted or combing wool are generally longer, and the object of combing is to remove the shorter fibers and place the remaining fiber side by side. This fact is the essential difference between the two divisions of the industry. In the final form, woolen cloths depend upon the shrinking of the finished fabric for density, while worsteds depend upon the density of the yarn which goes into them.

The wool is taken from the last cylinder of the machine in one large and unbroken rope, while in the woolen process it is left in small individual strands. As has already been pointed out, worsted is made up of the longer fibers. The wool combed out is known as noils, being the shorter fibers. It is an important raw material being blended with those known as clothing wools.

There are today three methods of producing worsted yarns. There is first the preparing and spinning of the true worsted thread which is composed of long fibers, which may also contain mohair and alpaca; second, the preparing and spinning of cross-bed and botany yarns; and last, there is the French system, which consists of the preparing and combing of short botany yarns. Aside from these used in cloth manufacture, there is a fourth class of worsted yarn used particularly in the manufacture of carpets and for knitting purposes, which is treated in the second manner.

In worsted manufacture great attention is paid to the production of the yarn. There are two chief methods in the worsted industry:

one known as the "Bradford" system, and the other as the "French" or "Continental" method. There is no need of going into a technical description of these processes, for it is sufficient to say that the yarns produced by the "Continental" method are softer and fuller and can be made from relatively shorter fibers, while the "Bradford" system makes a yarn of greater tensile strength and wearing qualities. This is suitable for fine dress goods and for men's serges and similar fabrics. The remaining processes in worsted manufacture parallel almost exactly woolen

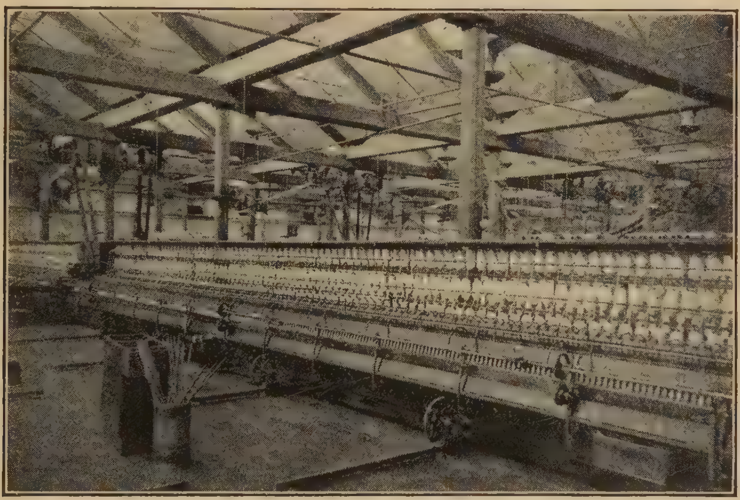

FIG. 5. — Worsted spinning.

manufacture, except that in some cases the worsted warp is doubled in order to give greater durability to the cloth. Inasmuch as worsted yarn is more dense, the shrinking or fulling process is of less importance than in the manufacture of woolens, while napping is done more to bring out the colors of the various yarns that have been used than to produce a novel finish.

Dyeing is a very fascinating subject because of the great ingenuity that has been displayed in its development. There are three major processes in use: top dyeing, yarn dyeing, and piece dyeing. In the first process, the loose fleece is put into the dye vats. It is the most thorough process, for the color readily permeates the fibers in this condition. Yarn dyeing is, as the name

implies, the application of color to wool in the yarn state. Piece dyeing is the coloring in the raw cloth. There are also, of course, numerous methods for printing designs on woolen cloth which have been developed to a highly satisfactory degree.

Growth of the Industry. The woolen industry has grown with great vitality since 1870. Professor Arthur H. Cole, of Harvard University, estimates that the number of employees has increased about 80 per cent and the number of looms by more than 90 per cent since that year. During the same period the consumption of raw materials has increased about 165 per cent. Professor Cole also estimates that the value of the output of the mills in 1919 shows an increase of approximately 600 per cent over the production for 1869. In that year the product of the woolen industry was valued at $177,500,000, while the figure for 1913 was estimated at $1,065,000,000. There has been a marked growth towards centralization and unification of the industry. Several large combines have resulted, which are confronted with the problems familiar to all such organizations. The result has no doubt been an increase in the efficiency and a lowering of prices through mass production.

There has been at the same time a marked change in methods of distribution. For many years manufacturers disposed of their products through jobbers and this is still done by many of them, but there is now a marked tendency toward direct selling. Sales rooms are now maintained by many important organizations in leading cities, where buyers for the trade and department stores may inspect the products of each manufacturer.

There has been a growth away from the heavier fabrics in men's wear. One of the reasons for this perhaps is the fact that our homes and offices are now so well heated that we may comfortably wear materials of a thinner texture. The trend towards lighter goods in England is, if present reports can be relied on, quite as clearly marked. As in this country, winter clothes for men in England were formerly of the 20 to 22 ounce weights, but it is now found that there is a much larger demand for those ranging between 13 and 17 ounces. As a natural outgrowth of this change heavier overcoatings are being worn.

There has evidently been a considerable improvement in the quality of goods made in the United States during the last half century. At the beginning of this period the fabrics were of a medium or low grade, but standardization has made it possible to

better the quality of staple goods. Since the War the tendency towards production of high-grade fabrics has continued.

Styles. In one respect the business of manufacturing clothes may be compared to publishing, for the mill must determine so far as it is able the type of goods which will most please the public, just as a magazine editor must shape his editorial policy along the same lines. Sometimes prior to the opening of the season the designers create a large number of patterns which are submitted to the executives of the mill.

A preliminary selection is made by them and the sales department is called into conference. The usual practice is then to have the designs woven into small samples which are in turn distributed to the agents or salesmen of the mill throughout the country. The goods to be manufactured for the season are determined by the orders received through the sales department. Results are often as startling and unexpected as those with which publishers are familiar. Sometimes it happens that the design which had not been highly considered by the experts proves to be the " best seller " of the season and may in time become a standard cloth.

Styles constitute one of the chief factors in the industry and require the most exacting judgment on the part of the manufacturer. Fifty years ago the production of broadcloth served as an index of the condition of the men's trade in the United States. More recently blue serge might have been used in the same way, but the attempts of experts to gauge the whole wool industry on the basis of one or the other would today lead to very inaccurate results.

Women's dress goods are even more likely to fluctuate. A Paris dressmaker will send a mannequin, actress, or society woman to the Longchamps races. If her clothes create a sensation, the material and cut will be copied the next day by other Paris dressmakers and in a short time a style set in Paris will migrate to New York and the cities of the world. It is, of course, well known that Paris is the world center of style for women because Paris is likewise the world center of amusement, having perhaps a larger leisure class than any other city. England, however, very often contributes to sport dresses and garments for out-of-door wear.

In the last two or three years there has been a marked tendency in women's styles to the use of silk and fur with a consequent reduction in the employment of wool fabrics. Rayon has been an

important factor in the styles. This new fabric, made from wood fibers, is increasingly important in the textile industry.

It is also felt that for the present at least the spending habits of men have changed; a marked increase in the sale of automobiles, the gigantic growth of the motion-picture industry, and the expansion of the luxury market have had their effect upon the production of men's goods. The heads of many households feel that their clothing is one factor on which they can economize for the purpose of buying an automobile or some other desired amusement.

Economies in food are so obviously undesirable that they are not often attempted by the average citizen who does not realize that economy in clothing is an almost equally shortsighted policy. Men today are frequently content with cheap suits which serve for one season and can then be discarded. They fail to realize that by spending a few dollars more they can obtain materials that will last twice as long and present a far handsomer appearance during the time of service. Then also the average citizen is content with one or two suits in place of the requisite three or four, for the average citizen does not realize that woolen cloth benefits by periods of rest in a way which cannot be compared to other fabrics. A suit that is allowed to hang in the closet for several days between each wearing will last considerably longer in hours of service than a similar fabric worn every day, for the reason that wool cloth tends to shrink back to its original shape if allowed to rest. There is, however, no doubt that the condition of the industry is bettering daily. People are beginning to realize a fact which has long been familiar to scientists and wool manufacturers that wool outwears all other fabrics and affords the best possible protection to the human body. No other material can supersede it for long if for no other reason than the fact that good woolens are the most economical of all clothing materials.

Perhaps the best index of the conditions of the industry are to be found in the figures on the opposite page which represent the consumption of wool throughout the United States from the season of 1909–10 to 1925–26.

Reports from abroad indicate that the American industry has somewhat more than held its own in what has amounted to a world depression. The English market suffered very great losses because of the general strike. The German industry, on the other hand,

is reported as being in a much stronger position than at any time since the war.

Fiscal Year	Pounds
1925–26	763,104,915
1924–25	560,789,811
1923–24	480,266,027
1922–23	786,280,320
1921–22	531,272,443
1920–21	616,271,075
1919–20	729,664,928
1918–19	727,184,575
1917–18	668,662,925
1916–17	662,892,094
1915–16	823,382,537
1914–15	587,357,195
1913–14	546,846,947
1912–13	498,836,447
1911–12	514,128,743
1910–11	454,583,398
1909–10	591,583,508

Tariff. One of the major problems affecting the industry in the United States is the tariff question. So far as raw wool is concerned it is found that many manufacturers favor the free admission of fleece into this country because of the lower price of foreign wool. The sheep raisers, on the other hand, very naturally speak for a strong protective tariff. Upward revisions of the tariff law took place in 1867, 1883, 1890, 1897, 1909, 1913, and 1922. The results of these changes, together with conditions in the world market from 1860 to 1926, may be summarized as follows:

1860–1870. The falling woolen market of 1860 changed to higher prices. A depression beginning in 1868 and continuing to 1870. The increase in the price of wool during this period is traceable not only to the tariff, but also to conditions created by the Civil War. The price of English woolens during the period continued moderate.

1870–1890. This period marked a gradual decline in the price of wool in the United States, despite high tariff. This condition was due very largely to the fact that there was a great increase of woolen production in the Southern Hemisphere. The wool prices in the United States were, in relation to other commodities, priced higher than in England.

1890–1896. The decline in wool prices continued to 1896, breaking sharply in 1894 when wool was placed on the free list at a time when the price in foreign markets was lowest ever known.

1897–1912. Wool prices rose after the 1897 tariff act and continued on a relatively high level during the Spanish and Boer wars, which

enabled the world to consume more than its average annual production. The curtailment of the Australian wool supply from 1895–1902 tended to increase the price of wool. The removal of wool duty in 1913 resulted in a slight revision in American prices.

1913–1926. The general derangement caused by the World War produced very high woolen prices which reached a level somewhat above general commodity prices. At its peak it was 180 per cent above pre-war level. The cutting down of the use of wool by the civilian population of Europe and America after the war resulted in a very rapid decline of woolen prices during 1920 and 1921. In this country the situation was helped in 1921 by the Emergency Tariff and in 1922 by the Tariff Act of that year. A general turn for the better of business conditions in the world resulted in a greater consumption of wool during 1922. As a result prices rose and reached a peak in 1924. The prices have dropped, however, since that time because of changes in styles and other conditions.

It may be observed from the foregoing summary that the changes usually expected from tariff revisions have not always occurred. Dr. Mark A. Smith, in his "The Tariff on Wool," has stated eleven reasons favoring free trade. These, with the critical opinions of Dr. Louis G. Connor, who has devoted many years to a study of the wool tariff, follow. He is of the opinion that only since 1922 has the country reached a stage of development where really conclusive data concerning the true need of a tariff on wool can be secured as the result either of countermand of a substantial tariff or removal of the tariff for a period of years. The opinions of the gentlemen follow:

Dr. Smith's Conclusions: 1. Wool is an essential raw material, the domestic supply of which is insufficient, and a duty raises the cost of living.

2. The duty has not greatly stimulated sheep and wool production.

3. Removal of the duty could have little permanent effect on domestic production.

4. Even if the duty stimulated production, its value to growers would be largely nullified by the ensuing larger production of and lower prices for lamb and mutton.

5. Future increases in wool production will take place on farms because range production has passed its zenith; on farms sheep and wool are of secondary importance. Keen competition has to be met from other uses for the land; lamb sales are of far greater

importance than wool, and farm production, therefore, is largely independent of the tariff.

6. The claim of vested rights is without force.

7. Other factors, particularly the land question, greatly outweigh the tariff.

8. The need for wool as a military necessity is easily cared for.

9. A duty on wool necessitates a compensatory duty on cloth, and complicates the competitive situation for the manufacturer.

10. The duty on wool is greatly pyramided, imposing a heavy burden on consumers of wool textiles.

11. This cost is so much greater than the direct benefit derived by wool growers and the relatively unimportant revenues received by the government, as to make a wool duty indefensible.

Dr. Connor's Critique: 1. There is no question that wool is an essential raw material; that the domestic supply is insufficient; that the duty raises the domestic price and that, to this extent, the cost of living tends to be raised. This may or may not constitute a valid argument for free wool.

2. To the point that the wool duty has not greatly stimulated sheep and wool production, the statement is made that while the duty has not increased the domestic wool clip since the middle eighties, the duty may have stimulated production to a much greater extent than indicated, *e.g.*, in the Rocky Mountain region. Entirely aside from the question of whether up to 1900 a wool duty had been the best policy for the country as a whole, it would seem clear that the tariff had markedly stimulated sheep and wool production until 1893, at least in all but the Rocky Mountain region, and that it did so for the Rocky Mountain region after 1896. If the wool duty, as generally believed, raised domestic prices by 7 cents per grease pound, or about 33 per cent from 1897 to 1913, then it follows that the tariff was of considerable importance to the range-sheep industry. To what extent this was true no one can determine accurately, due to the inconclusive results of free wool in 1913. This was partly due to the War, partly to a temporary rise in wool prices as a result of a severe Australian drought, and partly to the meat situation in the United States. Since 1922 the duty on wool would seem to have been a decided and stimulating benefit to the range industry.

3. It is rather a broad assumption to state that the removal of

the tariff would have little permanent effect on the domestic sheep industry, and such a conclusion is largely conjecture.

4. To the point that though a duty stimulated production, its value would be decreased by lower prices for lamb and mutton, the following reply is made: While there would be lower lamb and mutton, prices for them have been out of tune in recent years anyway. But further, any price decline in sheep and lambs would be appreciably tempered by the effect of the tariff on wool prices, if the wool duty is retained. The more lamb prices decline, the more important the duty on wool would become to sheep raisers.

5. To the statement that future increases in wool production will take place on farms, it is replied that while a future large increase will probably take place on farms rather than on the ranges, considerable gains can take place on the latter and are now being made. While sheep and wool are tending to be of secondary importance on farms the value of wool receipts in total flock receipts on general farms is practically the same as that of meat production. Therefore, the value of a wool duty to farm sheep raising is significant.

6. To the conclusion that the claim of vested rights is without force, it is replied that it is a matter requiring more careful study. In the Rocky Mountain region a large part of the relatively small area of crop land is irrigated. The bulk of the crops for at least two thirds of these lands is used mainly by stockmen to supplement their restricted ranges, and this outlet is of increasing importance. In this development sheep have played a great part, and the industry has been encouraged by the government through its irrigation and settlement policies. Without the sheep-industry market these regions are in a bad way.

7. Regarding the argument that other factors, particularly the land question, greatly outweigh the tariff, it is stated that these important factors all really center on the land question. This itself is a result primarily of the homestead entry on the open ranges. Due to the government's grazing homestead policy in recent years many settlers suffered great losses and have been disappearing, but in spite of handicaps the sheepmen have held on, and they held on in order to put to profitable use the otherwise unusable or only partly usable grazing lands.

8. That the need for wool as a military necessity is easily cared for is met by the opposing statement that during the Great War

the rigor of the measures taken by the Allies to conserve wool supply for military needs, the meagerness of the issues for civilian consumption, and the care taken to prevent supplies reaching the enemy indicate that experts consider wool supply a difficult wartime problem. Civilians could not well be clothed in cotton in the colder parts of the United States; and if sheep were not slaughtered, the clip would be increased, but not proportionately, because of the normal "pulled wool" production. It would be a costly increase. If the animals not slaughtered were distributed among farmers who "knew" sheep, then their systems of management would be disturbed and their normal productivity impaired at a time when their largest output of food and foodstuff would be desired. If the animals were distributed among farmers unacquainted with sheep management, the losses from improper care and disease would be appalling and the objects of the prohibition more or less defeated. Such a measure proposed during the War was abandoned as impracticable.

9. To the point that a duty on wool requires a compensatory duty on cloth, this is a small point that is unquestioned by Dr. Connor. Our manufacturers need a protective duty of up to 50 per cent on fabrics. Removal of the duty would in no way alter this protective need, which makes it entirely impracticable for them to compete in the export trade in wool textiles.

10. The free trader's point that the duty on wool is greatly pyramided, imposing a heavy burden on consumers of wool textiles, is questioned by Dr. Connor. The latter states that the free trader's estimates of the cost of the wool duty err in these particulars: (*a*) his preliminary assumption that the duty is fully effective on domestic wool prices; (*b*) the highly important differences between woolens and worsteds are nearly ignored; (*c*) the pyramiding assumption is inaccurate; (*d*) no attempt is made to evaluate the effect on cloth and clothing of increases in cost, other than for the raw material alone; (*e*) the effect of the wool duty on world prices is overlooked.

Dr. Connor declares that the tariff on wool has rarely raised domestic prices by the full amount of the duty. As a matter of fact, during the four years since September, 1922, domestic wools on the Boston market have averaged only about 16 cents per clean pound higher than London prices, for fairly comparable grades. Based on the average United States clip plus retained imports of

foreign wools, the estimated domestic consumption (not including carpet wools) has averaged approximately 236,000,000 pounds of clean wool per annum. Fifty-six per cent has been domestic fiber. These factors reduce any theoretical figure of cloth costs. There is no such definite pyramiding at each stage between wool grower and ultimate consumer. No one, from wool merchant to retailer, can add a definite percentage to cost to allow for normal profit in establishing their price. Profits, of course, depend on prices, but prices are determined by highly competitive conditions and must accord with well-established traditional figures. The profit, therefore, tends to be the difference between cost and the nearest trade prices, and the profit normally tends to decrease in percentage of cost as the selling price increases. If this pyramiding is true, then the profits of American wool textile mills would be greater than those of Europe by at least the amount of the duty. But this is not a true statement, according to certain wool manufacturers.

To the extent that the duty results in an increase in the domestic wool clip, the world supply of wool is increased and the world price is depressed below the level which would prevail if there were no duty. Only an indeterminate part of the excess of domestic over foreign prices as a result of a duty on wool, therefore, can be used in an attempt to calculate the real " cost " of the duty. In the nature of the case this real " cost " is less than would be suggested by the amount of the excess of domestic over foreign wool prices.

11. To the statement that the cost of a tariff is much greater than the benefit to wool growers, the protectionist claims that his previous arguments yield conclusions that this is merely a statement of opinion and not a conclusion from facts, for no one can arrive statistically at the true cost of the duty, or for that matter the benefits. Any true cost must be a net figure, a result of balancing benefits against costs.

The nature of the demand for wool makes it possible to raise the price by means of a duty. If, as a result, the domestic production be increased, American wool grades may displace much imported wool. But this applies only to a certain limited type of wool. For example, it cannot apply to carpet wool, for 100 per cent has to be imported because we produce none. Hence carpet wool might well be duty free. Again, since we produce a very low percentage of coarse wool such as the East Indies produce, such wool carries a low rate of duty. However, any increase in the

domestic output due to a wool duty will not be proportionate to the rise in price. The demand for mutton and lamb in this country is sufficiently restricted so that if flocks are increased to secure profits from the higher price of wool, the fall in the price of meat will, to some extent, offset the gain to sheep producers.

Of equal interest to the American public is the question of tariff on finished goods. It is generally felt among manufacturers in this country that the industry cannot exist without a protective tariff that is reasonably high. Even under the present law, there are certain grades of cloth that can be put down in this country from abroad, and placed on the market, with an 80 per cent duty paid, at a lower price than American manufacturers could market the same product. These goods are special weaves in which the labor cost is remarkably high. On the general run of goods where the principles of mass production can be applied, the manufacturers here can operate with satisfactory profit under present conditions

While labor costs represent in the neighborhood of 20 per cent of the sales price of staple fabrics, it is a very much smaller factor in the price paid by the public for a suit of clothes. It is none the less important to the manufacturers in the open market. The duty which manufacturers must pay on imported wool also makes a protective tariff on finished goods essential to the industry.

Labor Conditions. Labor conditions in the United States have had a serious effect upon the woolen industry and constitute today one of the chief problems with which manufacturers are confronted. Since 1870 there has been a gradual but marked reduction in the number of women and children employed in the industry, with a consequent increase in the ratio of adult male operators.

One reason for this increase in the number of male operatives was the influx of skilled immigrants during the latter part of the nineteenth and the first part of the twentieth century. They came largely from eastern Europe and produced a dual effect of somewhat increasing the effectiveness of the industry's personnel by making available a large number of adult male workers, and at the same time setting up within mills small racial groups which it was exceedingly difficult to Americanize or wield into a cohesive body.

This situation is particularly true in the fine worsted and woolen manufacturing around Passaic, New Jersey. The same condition prevails in Lawrence, where the foreign-born population as late as

1910 constituted 48.1 per cent of the total while 26.3 per cent were native born of foreign parentage. Five years later the foreign born and their children supplied 86.7 per cent of the total population of that city. The Philadelphia area has been able to obtain American-born labor more readily than any other textile district.

There has since 1870 been a continuous effort on the part of labor organizations to reduce working hours in the mills. The first progress in this direction took place in 1874 when the Massachusetts Legislature enacted a ten-hour law so framed that it could be forcefully administered. Before 1890 the remaining New England states had followed suit. Thereafter, New York adopted a similar law in 1886, and New Jersey six years later. According to a census taken in 1914, 55 per cent of wage earners in the woolen and worsted industry were averaging in the neighborhood of 54 hours a week. During the War period changes in working conditions went on rapidly. In 1915 it was found that the normal 54-hour week had been reduced to 48.

Inasmuch as a great part of the operations in woolen and worsted manufacture do not require skilled labor, one of the chief problems of the industry is the high labor turnover. This, of course, has a tendency to keep down per capita production and is at the present time the object of study by many manufacturers and recognized labor organizations. Some of the turnover may be due to the number of women employed which even now is considerably higher than in many other industries. Various plans for stabilizing the situation have been put forward by industrial engineers. These include a variety of works councils, plans for union coöperation, and profit sharing. Some are the outgrowth of sentimentalism while others are organic and sound and operating on a successful basis.

A feeling exists today that there is a decrease in the volume of turnover, due possibly to the application of some of the plans suggested above and partially to the efforts made at Americanization which have tended to make homogeneous a hitherto disassociated body. Then, too, the depression which has continued for several years within the industry and from which it is only now emerging has forced operators to cut down the number of their employees, and they have consequently been able to retain only the more skilled workers. This class, as in all industries, is the least liable to turnover.

Financial Growth. An examination of some of the leading companies in the industry will indicate its growth in the United States. The Arlington Mills, for example, were established in 1865, beginning with a nominal capitalization of $240,000. The business went through an experimental period lasting until 1876. The following year the capital stock increased to $500,000 in order to finance new buildings, thus keeping pace with the growth of business. At that time the employees numbered 600 and the annual output of the mill was five million yards of cloth. Further expansion in 1880 necessitated increasing the capital stock to $750,000. In 1881 the addition of a cotton mill raised this figure to one million dollars. Still further expansion in 1887 added half a million dollars more. In 1890 the erection of a spinning mill called for the investment of more capital in the plant and the stock was raised to two million dollars.

Six years later the figure rose to $2,500,000, and in 1902 crossed the three million dollar mark, while in 1905 it had grown to five million dollars, the increase of two million being made up by one million paid in and a stock dividend of equal amount.

In 1907 the capital was increased to six million dollars; in 1909 to eight million dollars by cash payments for stock issued at par; and in 1920 to twelve million. The report published on the sixtieth anniversary of this company shows that in the early period of its development 500 pounds of Canadian wool supplied the needs of the mills' machinery, while the wool consumption in 1925 of this organization amounted to the fleeces of 33,000 sheep daily and 1,500,000 pounds of wool weekly by the top mill.

The main plant is situated in Lawrence and Methuen, Massachusetts, while mills are also operated at Hoosac and North Adams in the same state.

The American Woolen Company, which is the largest single organization in the industry, was established through the initiative of the late William M. Wood around a nucleus of eight mills in Massachusetts, Rhode Island, and New York. The company was started in 1899 with a capital of approximately fifty million dollars, of which twenty million dollars was seven per cent preferred stock and $29,501,101 common stock. Between April 17, 1899, when the company started business, and June the following year twenty more mills went into the combination so that in 1900 the American Woolen Company had a production capacity estimated at thirty

million yards annually. In 1923, capitalization stood at ninety million dollars as the result of repeated expansion since the close of the World War.

In addition to the mills that were started and developed by American initiative and capital, certain others represent foreign investment. Through them some of the advanced European processes were introduced into the American industry. In 1889, for example, under the auspices of the German corporation, Kammgarnspinnerei Stoehr and Co., A. G., there was established in this country at Passaic, N. J., the Botany Worsted Mills under the laws of that state. The enterprise was supported by German capital and technique during its critical years.

The intervening years have been marked by sound growth until at the present time the Botany Worsted Mills at Passaic is the largest mill of its kind under one roof. In addition to this plant, a subsidiary is operated at Garfield, N. J. As of December 31, 1925, the Botany Consolidated Mills, Inc., had current assets of more than $24,600,000 and an earned surplus as of that date of approximately $1,770,000.

It is quite impossible to predict the future of the industry as a whole. The most significant movement at the present time is the formation of the Wool Institute, Incorporated. This body is being formulated on a basis similar to that of the Cotton Textile Institute, and according to a statement issued on February 1, 1928, by its sponsors, 47 per cent of the country's loomage has already pledged its support to the movement. There is no doubt great potential good could be derived from such an organization, which is in a position to consider the large problems of the industry on an impersonal and scientific basis.

During the past few years, woolen manufacturers in the United States have devoted much energy to modernizing their plants. The industry produces practically all lines of goods that are needed by the people of the United States and is in addition in close touch with the developments in foreign countries.

There is a general feeling, therefore, that the industry is on the up grade, following the extreme fluctuations to which it has been subject since 1914. We have reached the point where our woolens compare favorably with any in the world and in those fabrics that are susceptible to mass production, the American product is unsurpassed.

CHAPTER XXI

THE ZINC INDUSTRY

By Walter Renton Ingalls[1]

The zinc industry of the United States is much more important than either its capitalization or its personnel would statistically indicate. Its mining and smelting at present probably occupy about 25,000 men, hardly any more than that. I doubt if the total capitalization of mines and smelters would come to more than $100,000,000, referring to original investment value in so far as mining and milling equipment and smelting works are concerned. These estimates pertain only to the branch of the industry engaged in the production of spelter. Both the number of men and the capitalization would be increased by inclusion of the zinc oxide branch of the business. The New Jersey Zinc Co., which is by long odds the principal factor in that branch, has a capitalization of 500,000 shares, which have a present market value of about $190 and yield about 6 per cent in annual dividend. This includes its many diverse interests and to a certain extent duplicates what I have previously estimated for smelteries.

I am obliged roughly to make these estimates, which are not given separately in reports of the census or any other statistical body. Indeed, the production of zinc and lead are so closely interwoven in many of the mining districts of the United States that it would be difficult separately to enumerate the personnel or reckon the capitalization. I am offering these estimates simply with a view of affording an approximate idea of the magnitude of the zinc industry.

Looking backward, it may be assumed that the personnel has been at all times substantially in proportion to the annual producing capacity for spelter, impoverishment of ore and improvement of methods having been more or less offsetting factors. Modern plants, however, are better than the olden and undoubtedly there

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has been an increase in capitalization per unit of zinc-producing capacity, apart from the economic increase ascribable to rising cost of construction. The latter feature has played no great part in the capitalization of the zinc industry inasmuch as there has been relatively little new construction in it since 1916.

Uses of Zinc. The importance of the zinc industry rests in the usefulness of its products. Spelter, or metallic zinc, is employed extensively for coating iron and steel as a protection against the weather, zincked sheet wire and ware, or galvanized as it is miscalled, being familiar to everybody. The iron or steel to be coated is simply dipped in molten zinc. Brass is also a substance with which everyone is familiar. In it zinc is an essential constituent to the extent of 30 per cent to 40 per cent. Rolled into sheet and plate zinc finds a multiplicity of applications, so many that it would be almost futile to try to enumerate them.

Zinc oxide is used on a great scale in the compounding of rubber, and it is one of the major pigments. Zinc sulfide in conjunction with barium sulfate is the important pigment known as lithopon. There are many other uses of zinc and zinc salts.

As a commercial metal zinc was introduced from the East Indies, where it appeared as of Chinese origin, and coming through Dutch traders acquired the name spelter, derived from the Dutch spiauter. This name survives as the commercial designation of the metal emanating from the smelting furnaces. Zinc oxide, or zinc white, is the molecular combination of an atom of zinc with an atom of oxygen. It is produced by burning metallic zinc, which occurs with the production of a smoke of white oxide. The latter may be done directly from ore, in a single operation, instead of producing spelter and burning it as a second operation. In modern practice zinc oxide is made in both ways, the products varying in quality and cost.

The Franklin Mine. The zinc mine of the United States which has the longest history is that at Franklin Furnace, N. J., commonly known as Mine Hill, and now as the Franklin mine. This mine existed in pre-Revolutionary times, and there are records of attempts to work it as far back as 1774, but these were directed toward the treatment of the ore as an iron ore, not as a zinc ore. However, as an iron ore it was of too low grade, and contained too much zinc to permit of economical smelting, and the early attempts were failures.

About 1838, Dr. Fowler, a member of Congress, who then owned Mine Hill, furnished some of the red ore (zinkite) to serve as a source of spelter for making the brass for the Government's standard weights and measures, which had been ordered by Congress. The spelter was made at the Government arsenal at Washington. Dr. Fowler appears to have had definite ideas as to producing spelter on a commercial scale, but his experiments showed it to be necessary to free the red oxide from the associated franklinite, which at that time no one was able to accomplish.

The peculiar character of the ore of Mine Hill, and the early ignorance as to the precise nature of its constituents and the metallurgy of zinc gave rise to the most protracted and one of the most interesting mining litigations in the history of the United States.

In 1848 the Sussex Zinc and Copper Mining and Manufacturing Co. was organized to develop and utilize certain ores of Mine Hill, and on March 10 of that year Col. Samuel Fowler and his wife, to whom the property had descended, deeded to that company " all the zinc, copper, lead, silver, and gold ores, and also all other metals and ores containing metals (excepting the metal or ore called franklinite, and iron ore when it exists separate and distinct from the zinc)" on Mine Hill farm. On the same day Fowler deeded to the same company " all the metal, mineral, or iron ore, usually designated and known by the name of franklinite," within certain lines on Mine Hill, the area covered by this second deed being included within the limits covered by the former deed. The zinc deed as first drawn excepted franklinite when existing separate and distinct from the " other ores "; but before signing, " other ores " was erased and the words " the zinc " inserted. The wording of this deed gave rise to the litigation which followed.

The Stirling Mine. In 1849 the New Jersey Exploring and Mining Co. had acquired the northern half of Stirling Hill (Ogdensburg), where the red oxide was more abundant, Stirling Hill being a few miles distant from Mine Hill. Although there has been much exploration for other ore deposits in this vicinity none but these two have been discovered. Both the Stirling and Franklin mines are still operated and both still rank among the major zinc mines of the world. They are noteworthy not only for the great magnitude of their mineralizations, but also for the uniqueness of its character. These two mines are the underpinning of the New Jersey Zinc Co.

Attempts were promptly made to work the Stirling ore for metallic zinc, this being undertaken by Richard Jones at Newark, N. J., in 1850, the ore being charged into Belgian retorts, but the experiment proved a failure, owing to excessive breakage of the retorts. Attention was then directed to recovery of the zinc as oxide, and a furnace constructed of fire-brick with a large clay muffle was designed, which withstood the corrosion better than the Belgian retorts. A row of these was erected in connection with a muslin-bag apparatus (invented by Samuel T. Jones) to collect the fume, and the manufacture of zinc oxide was begun.

The Wetherill Process. The idea of Jones did not prove satisfactory until in 1851 Samuel Wetherill, of Philadelphia, invented the process, since known as the Wetherill process, by which the extraneously heated muffle was done away with. In his improved method the ore mixed with anthracite coal was thrown in a layer 3 to 4 in. thick upon a hearth composed of perforated cast-iron plates, 1 in. thick; the door was closed and cold air blown under the grate, which passing through the charge raised the temperature to such a point that the ore in contact with the carbon was reduced to metallic zinc, which vaporized and oxidized, passing off as a white smoke to the collecting apparatus, where the products of combustion strained through the muslin bags, leaving the oxide inside of them. This process proved so successful that it was introduced immediately and has remained in use without essential change up to the present time. It was not only the first important contribution that America made to the metallurgy of zinc, but also was perhaps the greatest, even as we now look backward 75 years.

The success of this new process led in 1854 to the institution of another enterprise for its application, which was done under the name of the Passaic Zinc Works, the plant being at Jersey City.

The New Jersey Zinc Co. An arrangement had been effected to consolidate the Sussex company and the New Jersey company, and in 1852, the New Jersey Zinc Co. was organized for this purpose and acquired title to "all the zinc and other ores, except franklinite and iron ores," on Mine Hill; the change in wording from the deed of 1848 being introduced to avoid future misunderstanding as to the intended reservation in the Fowler deed, the object being to convey to the New Jersey company all that the Sussex company had acquired from Fowler.

On Dec. 13, 1850, Col. Samuel Fowler had deeded to the trustees of the Franklinite Mining Co. all the reserved iron ore called franklinite, with all other reserved ores and metals on Mine Hill farm not conveyed to the Sussex company by the deed of March 10, 1848. At this time, therefore, there were two companies making claims to different ores occurring in the same deposit. The litigation that arose naturally over this complicated association of interest and the commercial and technical vicissitudes of the early companies have been described in my book "Lead and Zinc in the United States," and it is unnecessary for me to rehearse it here. It is sufficient to summarize that the Franklinite Mining Co., and its successor, the Boston Franklinite Co., failed technically, and the zinc ore deposit of Stirling Hill and a large part of that of Mine Hill passed into the hands of the New Jersey Zinc Co., which was then reorganized as the New Jersey Zinc and Iron Co. This was in 1880. In the new company Moses Taylor became the dominant factor when he advanced money to it, receiving one half its stock and purchasing a few shares additional for control.

The New Jersey company, which began with the manufacture of zinc oxide, soon entered upon the manufacture of spiegeleisen, and shortly after the Civil War it began making spelter from by-products of the manufacture of zinc oxide and spiegeleisen, an addition to the Newark plant being made for this purpose. In 1892 the Newark plant was practically rebuilt, making it the best of its kind for that time.

The Lehigh Zinc Co. While the early developments were going on in New Jersey, a contemporaneous exploitation was being made of the mines at Friedensville near Bethlehem, Pa., where discovery was made in 1845. Mining on an extensive scale was begun in 1853 by the Pennsylvania and Lehigh Zinc Co., which in 1856 erected smelting furnaces of the Silesian type and a zinc oxide plant at South Bethlehem. The spelter furnace failed to yield any zinc. Neither the anthracite coal nor the retort clay seemed to be adapted to the purpose, while the ferruginous-calcareous character of the ore obtained at Friedensville was a continual source of trouble. It was not yet known in America how to smelt such ore. The Pennsylvania and Lehigh Zinc Co. was, within a few years, converted into the Lehigh Zinc Co.

Matthiessen and Hegeler. In 1857, F. W. Matthiessen and E. C. Hegeler, who had just come to the United States from the school

of mines at Freiberg, Saxony, obtained permission from the Lehigh company to experiment on their own account at the abandoned plant. They did it on a small scale, using one muffle placed in a kiln altered for the purpose. They demonstrated that anthracite, as well as New Jersey clay, could be used, and made some spelter in this experimental way, but failed to come to an agreement with the owners of the property for building works, largely on account of the financial crisis prevailing at that time. They then turned their attention to the West, where they studied the zinc deposits of Wisconsin, and late in 1858 began the erection of the present works at Lasalle. Lasalle was selected as the point where the Illinois coal field approached nearest to the Wisconsin zinc mines. These works went into operation in 1860, and have continued without interruption to the present time as of the Matthiessen and Hegeler Zinc Co.

Zinc Mining in Wisconsin. It cannot be said definitely when zinc ore was first identified in Wisconsin. Probably it was known from the beginning of lead mining there, owing to the occurrence of the lead and zinc ores in intimate association, but for many years there was no market for the zinc ore. At some time between 1850 and 1860, Georgi, an old Silesian smelter, is said to have built a zinc works in Wisconsin, but his undertaking was unsuccessful. Possibly there were other attempts of the same character; if so, they were equally unsuccessful. Certainly there was no market for the zinc ore of Wisconsin until Matthiessen and Hegeler built their plant at Lasalle.

In 1870 the Illinois Zinc Co. erected a plant at Peru, which adjoins Lasalle. From 1860 to about 1873 these smelters derived their entire ore supply from Wisconsin, but the business was done on a very small scale, and the zinc production of the West did not begin to expand largely until the mines of the Joplin district of Missouri sent forward large supplies of ore. The failure of the miners of Wisconsin to rise to the situation was partly due to their primitive methods and partly to the association with their ore of the objectionable marcasite, which could not be successfully separated. This condition existed until 1904 or 1905.

Friedensville Pa. From 1861 to 1876 the mines at Friedensville, Pa., were extensively exploited, successful zinc smelting having been accomplished about 1861. The most important of these mines was the Ueberoth. The other mines of this place

were the Hartmann and the Saucon. The Passaic Zinc Co. operated one of these mines for a little while, but the chief operators in this field were the Lehigh Zinc Co. and the Bergenpoint Zinc Co. In 1879 all the property of the Lehigh Zinc Co. was foreclosed by its bondholders and in 1880 its mines passed into the hands of the Bergenpoint Zinc Co. The latter company had a dressing works, smeltery, and oxide plant at the Saucon mine, and also had a smeltery at Bergenpoint, N. J. The ore of Friedensville was remarkable for its freedom from lead, arsenic, and other impurities that affect injuriously the quality of the spelter, and the metal that was produced at Bergenpoint had great fame for its superior quality.

All of the mines of Friedensville were worked as open pits. The greatest difficulty in their operation was the strong influx of subterranean water. Even at the depth of 46 ft. in the Ueberoth mine the flow was already large. At the depth of 150 ft. it was found necessary to install what was then the largest pumping engine in the world. This pump was able to handle all the water that came to it, the flow in 1876 being as great as 20,000 gallons per minute. The cost of pumping water came to about $4 per ton of ore produced, which was a serious handicap, and in 1876 the Lehigh works becoming able to obtain a supply of cheaper ore from New Jersey, the Ueberoth mine was abandoned. It was reopened by the Bergenpoint Zinc Co. in 1883, but it was not operated long, the entire business of that company being wound up in 1886, when its smelting works were closed. The Friedensville Zinc Co. erected a small smeltery at the Ueberoth mine in 1888, and toward the end of that year began making "Bergenpoint" spelter. The Ueberoth mine was reopened in 1890, but its operation was brief. No mining has been done at Friedensville since that time. Eventually all the mines of this district were purchased by the present New Jersey Zinc Co., which holds them in reserve.

Zinc in Missouri. Small deposits of calamine were early known to occur in the lead district of southeastern Missouri. In 1867, George Hesselmeyer erected a furnace at Potosi, which did not continue long in operation. In 1869 the Glendale works were established at St. Louis, to which the Valle mines became immediately a large shipper, the zinc ore developing into a greater source of profit than the lead ore, previously exclusively mined. Several

other works were soon afterward erected at and near St. Louis. Zinc ore had been recognized in the Joplin district from almost the beginning of lead mining, but there was no local market for it and no means for getting so crude a commodity to the smelters further east. In 1870 the St. Louis and San Francisco railway was completed to Peirce City; early in 1871 it was extended to and beyond the State line.

In 1871 an agent of the Missouri Zinc Co. of St. Louis began to work for zinc near Granby. In 1872 zinc ore was shipped from Joplin to the Illinois Zinc Co. at Peru, Ill. It brought only $3 per ton, but the price soon rose to $15. In 1873 zinc smelting was begun at Weir, Kans. The new market for ore revived several of the old lead-mining camps. Thus the discovery of lead ore at Joplin had drawn miners away from Granby, but the utilization of the zinc ores brought about not only a renewal of mining operations, but also an entire change in the character of the work. Exploitations became deeper and larger, though still of a crude character. In 1877 the discovery and development of the mines at Galena, Kans., gave an additional impetus to mining, while the market for ore was further increased by the erection of a smeltery at Pittsburg, Kan., in 1878.

At the End of the Civil War. Up to the end of the Civil War the production of zinc in the United States was small. Statistics for this period are unavailable, but it is doubtful if the production in any year previous to 1870 was much in excess of 5000 tons. In 1870 it was probably about that figure. Nor was consumption very much larger, the importation of spelter and sheet zinc being relatively small. The Civil War undoubtedly gave an impetus to zinc production in the United States (but the military requirements for brass at that time were nothing like what they proved to be in the World War), and it was a fact that the United States did not then possess many known deposits of zinc ore of a character easily amenable to beneficiation. Such an enjoyment did not happen until the ore deposits of the Joplin district — easily mined, easily concentrated, and easily smelted — were developed. As early as 1875 the Joplin district was furnishing the ore from which 75 per cent of the spelter output of the United States was derived, and ever since then it has occupied the premier position among the zinc-producing districts of the United States. The term "Joplin district" is of course a broad one, comprising an area of about 35 by 15

miles, overlapping the cornering of Missouri, Kansas, and Oklahoma, wherefore it has in recent years come to be known as the "Tri-state district." During the last 15 years the Oklahoma part of it has been the most important.

Early Mining at Joplin. The methods of mining and ore dressing in the Joplin district in 1871–1880 were very crude. The shafts were mostly very shallow and rudely timbered, timber not being employed at all except where absolutely necessary. The ore was hoisted in small buckets either by whim or by windlass, often the latter. If the mine made any water, the latter was hoisted out in the same way. Little or no attention was paid to ventilation. The operations were conducted generally by lessees. The owner of a tract of land leased it to a party or company for exploitation, the lessee paying a percentage of the mineral obtained as royalty to the owner. The first lessee sublet in parcels 100 ft. or 200 ft. square to miners, who would open the ground, the latter paying an advanced royalty. The ore was crushed with rude breakers, and was concentrated with hand jigs.

Substantially the same conditions continued to exist in 1881–90. Steam engines were introduced for hoisting, but horse- and man-power were more commonly employed as late as 1891. The mines seldom, if ever, had shaft houses, and the work being performed in the open was subject to general interruption during periods of inclement weather.

Early Metallurgy. The smelting methods were equally crude. Except at Lasalle the distilling was done in crude forms of the Belgian furnace, whose chimneys flamed like torches, picturesque but wasteful. The consumption of coal per ton of ore was large and the percentage of zinc extraction was low. The ore was unassayed and no one thought of such a thing as a metallurgical balance sheet or would have known how to compute it. Starting with the crude ore from the mines, the ultimate extraction was probably less than 50 per cent of its zinc. Edward C. Hegeler at Lasalle was the only man in the western branch of the zinc industry who possessed real metallurgical knowledge. He had already designed and put into use in 1872 his elongated furnace, fired with producer gas, and operated with some mechanical adjuncts. This type of furnace is still extensively in use. Some of us have criticized it as bad engineering, but at the time of its introduction it was certainly ingenious and an important step in advance.

Following Jones, who introduced bag filtration, and Wetherill, who introduced his special grate and furnace, developing the Wetherill or American direct process of zinc oxide manufacture, Edward C. Hegeler was certainly the man who made the greatest impression upon the American zinc industry. About 1882 Hegeler designed and put into operation at Lasalle his muffle-roasting furnace and commenced the manufacture of sulfuric acid as a by-product from Joplin and Wisconsin blende. The Hegeler roasting furnace continues in use for this purpose substantially as introduced in 1882. As early as 1868 Hegeler had begun the rolling of sheet zinc at Lasalle. The Illinois Zinc Company at Peru in 1882 instituted the same manufacture. Ever since that time these two concerns have been predominant in the manufacture of sheet zinc in the United States.

About 1880 the St. Louis and San Francisco, the Missouri Pacific, and the Kansas City, Fort Scott and Memphis railways were extended into Jasper County. Mining was vigorously conducted and camps multiplied in the vicinity of Joplin, and around Webb City and Carterville, along Spring River, Center Creek, and Turkey Creek, and especially in the vicinity of Galena, Kans. Early in 1886 development was begun on the mines at Aurora, Lawrence County, Mo. By 1890 the population of Joplin had grown to 10,000; that of Webb City and Carterville to 8000; and that of Carthage to 8000.

1880 to 1890. In 1880 the spelter production of the United States was about 23,000 tons. Up to this time the major part of the production was still from the Joplin district, the output from the mines of New Jersey and Virginia being only about 5000 tons per annum. However, the mines of New Jersey were yielding about 8000 tons of zinc a year in the form of oxide.

Besides the introduction of the Hegeler furnace in 1882 and the institution of by-product sulfuric acid manufacture, an interesting metallurgical event of the eighties was the introduction of the Siemens regenerative distilling furnace according to the design introduced at Auby in France. In the United States these furnaces were built at Pittsburg, Kans., by the Granby Mining and Smelting Co.; at Rich Hill, Mo., by the Southwestern Lead and Zinc Co.; and at Peru, Ill., by the Illinois Zinc Co. At Pittsburg and Rich Hill they were soon abandoned, probably for the reason that their operators did not know how to handle them; or perhaps for the

reason that coal was so cheap as to make economy in its use relatively unimportant. At Peru, on the other hand, their use became established and has continued ever since. At the present time this furnace is employed at four of our American smelteries. It permits the smelting of a ton of roasted ore with as little as 0.9 ton of inferior coal (for combustion purpose) and is the most efficient distilling furnace that we have. Its use has not become more general for the reasons that its first cost is high and with us coal is relatively so cheap that economy in its use is less important than in Europe. In American zinc smelting the economic conditions have always pointed toward carelessness in respect of fuel but carefulness in labor, which has been just the opposite of the European principles under conditions where coal is dear and labor is cheap.

1890 to 1900. At the beginning of the last decade of the 19th century production of zinc in the United States was about 80,000 tons as spelter and 19,000 tons as oxide (24,000 tons of oxide). The chief factors in the business in the east were the New Jersey Zinc and Iron Co. (Moses Taylor and S. S. Palmer), the Passaic Zinc Co. (Manning and Squier), the Lehigh Zinc Co. (Joseph Wharton and the Wetherill family). These companies produced all of the oxide and about 9000 tons of spelter. The Bertha Mineral Co., and Edes, Mixter and Heald Zinc Co. in Virginia and Tennessee respectively, produced about 4000 tons of spelter. In Illinois the Matthiessen and Hegeler Zinc Co. and Illinois Zinc Co. produced about 29,000 tons. The Edgar Zinc Co., owning the Glendale Works at St. Louis, and the Granby Mining and Smelting Co., with works at Pittsburg, Kans., were enterprises of St. Louis capital. The remaining factor of importance was Robert Lanyon and Sons operating at Pittsburg and vicinity, who had been pioneers in the smelting of Joplin ore, Robert Lanyon having been previously engaged in zinc smelting at Lasalle and having early located himself in the new district.

About 1890 improved methods of mining and milling, especially the latter, began to be introduced in the district. In 1892 there were five steam mills in operation near Joplin and 60 producing shafts, while Webb City, Carterville, and Galena were smaller producers. The producing capacity of the district already promised to be so large that disposition of the surplus engaged serious attention. With the object of developing a foreign market, the Southwest Missouri and Southeast Kansas Lead and Zinc Mining

Association sent an agent to Europe in 1891. As a result of this about 3000 tons of ore were exported in 1892, but the business ceased because after deducting the transportation charges the producers did not realize so much as they could in the home market in spite of the low prices here. From time to time several other attempts were made to export Joplin ore when dissatisfaction was felt as to the domestic market, but the results were always the same.

The next few years witnessed a steady and important development in the district. Operations gradually came to be conducted on a larger scale. The number of steam mills rapidly increased. The amount of work done in the open air decreased. Mining thereby acquired a far greater regularity than it had previously displayed. By 1898 operations had settled down to a well-defined, though peculiar, and in many respects a still crude practice. However, this had been developed to suit the special conditions, and in general the industry was profitable.

During the '90s most of the zinc smelters of the United States still used a rough form of the Belgian furnace such as was originally introduced at Liège. In the East and the West these furnaces differed only as to their grates and fire boxes, the Eastern smelters using anthracite coal and the Western bituminous. Producer-gas firing was employed at only two works, viz.: Lasalle and Peru. With the exception of Lasalle and Peru all of the American zinc smelters at this time were very small affairs.

Natural Gas Smelting. About 1896 B. F. Hobart, of St. Louis, consolidated a large number of the small smelters at Pittsburg, Kans. and vicinity under the name of the Cherokee-Lanyon Spelter Co. This consolidation, about contemporaneous with that of the New Jersey Zinc Co. in the East, constituted the first attempts to create larger units in the American zinc industry. The Cherokee-Lanyon Spelter Co. was not, however, destined to survive long.

Toward the end of this decade other important events occurred. The Spanish War had ended and the following industrial boom had begun. Among other things this brought about a sharp rise in the value of spelter, more attention was consequently attracted to the zinc-producing industry, and Boston capital was invested in the Joplin district, where mining had previously been mainly a local affair. A few years previous natural gas had been developed at Iola and Cherryvale in Kansas, and zinc smelteries, employing it as

fuel, had been built at those places. In the early days it was not known how to burn the gas properly, and although operating cost was low zinc extraction was also low, wherefore in 1899 it was still nip and tuck between the gas smelters and the coal smelters. Within a year or two, however, it was learned generally how to burn the gas, and its economy was so great that the coal smelters could no longer compete; their plants were abandoned in 1901, and the Cherokee-Lanyon Spelter Co. soon afterward passed out of existence. There were then halcyon days in zinc smelting, when a relatively large plant could be operated from a 4-inch gas well driven in the yard and there were no ashes to be handled away. At this time there were, by this bounty of nature, the lowest smelting costs ever enjoyed.

The cheap zinc smelting of these days was done in spite of the fact that at this time there was scarcely any scientific management in the Western practice of the art. The utilization of natural gas was indeed sadly bungled. It had previously been used on a small scale in Indiana, and in a correct way there, but only S. C. Edgar, in building his smeltery at Cherryvale, appreciated the true principles. The other smelters borrowed the long Hegeler furnace from Lasalle and tried to adapt it to natural-gas firing. Eventually they did so, creating the Iola type of furnace, but they experienced vexations and vicissitudes in achieving this, while Mr. Edgar was pursuing the even tenor of his way and getting good results from the beginning.

New Jersey Consolidation. In 1897 the New Jersey Zinc and Iron Co. was reorganized as the New Jersey Zinc Co., acquiring all the capital stock of three other companies, viz.: (1) the Passaic Zinc Co. with mines at Ogdensburg, N. J., and Bertha, Va., works for the manufacture of zinc oxide and spelter in Jersey City, and a blast furnace for manufacturing spiegeleisen in Kearny township between Jersey City and Newark; (2) the Lehigh Zinc and Iron Co. with a mine at Franklin and works at Bethlehem, Pa., for the manufacture of spelter, oxide of zinc, and spiegeleisen, and works at Freemansburg, Pa., for the manufacture of zinc oxide by the French process; and (3) the Mineral Point Zinc Co., with works making lead oxide of zinc at Mineral Point, Wis.

In the consolidation Stephen S. Palmer of the original New Jersey company and August Heckshcr of the Lehigh company became the leading spirits. John Price Wetherill, inventor of the new and

important process of magnetic concentration, who had previously been associated with the Lehigh company, became an important figure in the new company.

Shortly after the consolidation the New Jersey Zinc Co. acquired the Empire Zinc Co., having mines and a spelter plant at Joplin, Mo., and a small plant at Waukegan, Ill., for the manufacture of spelter. A little later it acquired the Bertha Mineral Co. with a smeltery at Pulaski, Va., and mines at Delton and Austinville in that state.

A highly important feature of the consolidation of 1897 was the termination of the litigation respecting the titles to the various minerals at Franklin, litigation that had been going on nearly continuously since 1848.

When the New Jersey Zinc Co. started in business, it had as its prime object the direct or American process of making oxide of zinc as being cheaper and better adapted to its ores than the indirect or French process. The French process, while much more expensive, produced and still does produce an oxide of a purer white that is better adapted for certain purposes.

Perhaps the most important result of the consolidation of 1897 was the improvement in the methods of dressing the Franklin ores. Among the assets acquired in the consolidation were the Wetherill patents for the separation of these ores into their constituent minerals. The processes covered by these patents were already in operation by the Lehigh Zinc and Iron Co. They embraced the use of a new type of magnetic separator, greater in power and efficiency than any previously known and capable of lifting very slightly magnetic minerals. The use of this invention made possible the separation of the ore into four classes, viz.: (1) franklinite, a mineral containing zinc, iron, and manganese, which is used for making oxide of zinc, the residue of which — much richer in iron and manganese than the original ore — is smelted for spiegeleisen; (2) willemite, a rich and pure silicate of zinc, which can be smelted directly for the production of high-grade spelter; (3) a product containing enough zinc to be valuable for the manufacture of oxide but giving a residue too low in iron and manganese to be worth smelting for spiegeleisen; (4) waste material which is now used extensively in the State of New Jersey for road building.

This separation of the ore gave much better raw materials for the several smelting processes, enabled the company to treat the

ore at a lower cost and with better recovery, and permitted each fraction to be treated in the most suitable manner. In providing a material which was directly available for the spelter furnaces, the new method of concentrating the ore also greatly increased the quantity of high-grade spelter that it was possible to make from the ore.

The original concentrating mill at Franklin, which was purely experimental, was replaced in 1899 and 1900 by a new one capable of treating all the ore then produced from the mines. As the business has increased this mill has been enlarged and improved in many respects.

The Beginning of the 20th Century. At the beginning of the 20th century the production of zinc in the United States had increased to about 140,000 tons of spelter and 37,000 tons in the form of oxide. The increase in spelter production had been wholly in the West, that of the East remaining about the same as 10 years previously, although oxide production had increased. The chief factors in the business at this time were the New Jersey Zinc Co. in the East, Matthiessen and Hegeler and Illinois Zinc Co. in Illinois, the Cherokee-Lanyon Spelter Co. in Missouri and Kansas, and the Edgar Zinc Co. with its Glendale and Cherryvale works. The Edgar Zinc Co. had recently been acquired by the American Steel and Wire Co., which was eventually to pass into the United States Steel Corporation. The American Zinc, Lead and Smelting Co. was beginning to smelt in Kansas. The Granby Mining and Smelting Co. continued to be an important mining concern, but had retired from the smelting business, which later it was destined to reënter.

About 1901 several of the smelteries at Iola, Kans., that had been owned by members of the Lanyon family were acquired by New York interests, who formed the Lanyon Zinc Co., which undertook to roll sheet zinc. The United Zinc and Chemical Co. (August R. Meyer) and the Prime Western Spelter Co. (subsidiary of the New Jersey Zinc Co.) were formed. These concerns operated at Iola. In the course of time their plants became useless through the exhaustion of the Iola gas pool.

The American Metal Co. entered the zinc smelting business, acquiring plants in Oklahoma; also the National Zinc Co. (Beer, Sondheimer and Co.). Later on came the Eagle Picher Lead Co. and the Grasselli Chemical Co. The last concern introduced the innovation of roasting the blende at several of its sulfuric acid

works and forwarding the roasted ore to a smeltery, using natural gas at Clarksburg, W. Va. Subsequently another plant, also using natural gas, was erected at Meadow-brook, W. Va., and more recently a coal-fired smeltery at Terre Haute, Ind.

Advent of Rocky Mountain Ore. A highly important event of the early years of the 20th century was the turning of attention to the relatively low-grade and unclean ores of Colorado, which previously had been scorned by American zinc smelters, and even pronounced impossible, but were now becoming more interesting in view of the increased cost of Joplin ore, following the exhaustion of the rich lens deposits.

The existence of zinc ore in the states and territories west of the Rocky Mountains was known from the earliest days of occupation, but for many years there was no market for it. In 1882 shipments of zinc blende were made to Peru, Ill., from the Cotopaxi mine, Fremont County, Colo., where there was a vein of comparatively clean ore; but whether from the smallness of the vein, from the high transportation charges, or the character of the ore, the business did not develop.

It remained for the introduction of improved crushing machinery, the invention of the Wilfley table (in 1896), and the magnetic and electrostatic processes of mineral separation to make it possible to obtain a concentrate reasonably suitable for zinc smelting out of the general run of the mixed sulfide ores of the Rocky Mountain region.

The great development of zinc mining in the Rocky Mountains dates from 1899 when some trial lots of concentrated ore were shipped from Creede, Colo., to smelters in Kansas. In the same year an enterprising ore broker obtained contracts with European smelters which enabled him to buy and export large quantities of ore from Leadville, Colo. The freight rate from Leadville to Antwerp, Swansea, or Hamburg was $9 per ton. The miners were glad to sell the ore for $5 per ton f.o.b. cars, it previously having been a waste product, and a large business developed. For several years this ore was mostly exported, American smelters, accustomed to the high-grade ore of the Joplin district, having great difficulty in smelting it successfully, but they finally succeeded and then promptly excluded the European smelters from the American market. After that, the production of zinc ore was inaugurated in nearly all of the Rocky Mountain States, the improved methods

of concentration rendering it possible to make marketable ores that previously were valueless, the requirements of the zinc smelters for raw material causing them to bid up the price, and the railways making freight rates on zinc ore so extremely low that it was possible to fetch ores to Illinois and Kansas from points so remote as British Columbia and Mexico.

Improvement of Methods. During the first decade of the 20th century steady progress in the zinc industry was made and numerous important changes occurred. The high grade, but individually small, lens deposits of ore in the immediate vicinity of Joplin were exhausted, and mining was diverted to the relatively low grade but more extensive deposits of " sheet ground " to the east and northeast of Joplin, stretching from Duenweg to Webb City. These deposits were of the nature of bedded deposits, which could be tested by churn drilling and estimated as having a probable yield of so many tons per acre. For the first time it became possible to estimate a Joplin mine as having a probable life at a given rate of production for many years ahead. The outrageously wasteful methods of concentrating the ore began to be corrected by the introduction of slime tables. Iola was the chief center of zinc smelting in Kansas. In the course of time the Iola gas pool began to be exhausted, but the southwestern march of the developers of the mid-continental oil field had begun and their operations discovered new gas pools to the south and southwest. Zinc smelting followed these developments and new plants were built at Caney and Dearing in southwestern Kansas, and at Bartlesville, Blackwell, Collinsville, and elsewhere in northeastern Oklahoma. The zinc smelteries to use natural gas as fuel were always of relatively light and cheap construction, and plants were built and abandoned without great concern. It was recognized that the life of any gas pool would be short, and consequently any new enterprise had to be figured on short amortization. The Cherryvale plant of the Edgar Zinc Co. was the best construction, and it has now been in operation for nearly 30 years, but in such an instance it became necessary to reach out for gas with longer and longer pipe lines, and to do more and more drilling, and the cost of fuel has increased greatly over what it was in 1901.

During this decade the less docile zinc ore of Colorado and other Rocky Mountain States, which originally had been exported, became more and more a factor in the supply of domestic smelters,

which acquired the smelting of it wholly for themselves, with the result that exportation ceased. This necessitated acquisition of better knowledge of the art of zinc smelting, so as to be able to handle these ores, relatively high in iron and lead, which previously had been troublesome to the American smelter. It may be considered, indeed, that the decade 1901–10 was that in which American zinc smelting was put upon a scientific basis. The American Smelting and Refining Company became interested in the industry, and in conjunction with a Belgian zinc smelter erected in 1901 a smeltery at Pueblo, Colo., this plant being laid out on Belgian lines. The New Jersey Zinc Co. through its subsidiary, the Mineral Point Zinc Co., built a large smeltery at Depue, Ill.; while through its subsidiary, the Empire Zinc Co., it acquired numerous mines in Colorado, New Mexico, and Arizona and erected a magnetic separating plant at Canyon City, Colo., for the preliminary beneficiation of the ores. At this time the New Jersey Zinc Co. was the most enterprising of all American zinc interests in policies of expansion and metallurgical improvement. It had already (in 1899–1901) erected its great plant at Palmerton, Pa., in which was exemplified the most modern practice of the art of zinc smelting, and scrapped the old plants at Jersey City, Newark, and Bethlehem.

Joplin Sheet Ground. As previously remarked, at the beginning of the 20th century, the major part of the spelter produced in the United States was derived from the Joplin district, and from the relatively rich lens deposits in the immediate vicinity of Joplin. It was only a short time, however, before they began to fail and the center of mining was shifted to the so-called sheet ground deposits, costs of mining and milling being trimmed in order to conform to the lower grade of their ore. No ore deposit is inexhaustible, however, the sheet ground of Webb City and Duenweg being no exception, and in the course of time it became necessary to exploit a lower and lower grade of ore, which meant that more and more tons had to be mined to produce one ton of the standard grade of concentrate, containing 60 per cent zinc. Although the cost of mining and milling per ton of crude ore was curtailed the cost per ton of concentrate rose, which had an effect upon the price for spelter. The Western ores helped the situation. In 1905, out of a production of 190,000 tons of Western spelter about 54,000 tons was derived from ore mined west of the Rocky Mountains, includ-

ing British Columbia and Mexico. Ere long, however, even the supply of Western ore appeared to be waning, and around 1910 it looked as if the trend of spelter price would be definitely upward, owing to inadequate ore supply.

Extension into Oklahoma. Such a trend was spectacularly reversed, however, by the discovery of a major extension of the Joplin district into Oklahoma, about 15 to 20 miles southwest of Joplin. Developments in this new part of the district were made rapidly, the ore proved to be relatively rich, and it was not many years before a rate of production was attained, surpassing what had ever been in the older parts of the region, and many new fortunes were built. The new zinc ore deposits in northeastern Oklahoma occurred to a large extent in the Quapaw reservation, wherein the lands were held by individually restricted Indians. Their lands were leased to operators under the ægis of the Department of the Interior, and many of these Indians became extraordinarily enriched by their royalties. In 1925 there were 43 Quapaw Indians with allotments whereon lead and zinc ores were mined. The tonnage of ore obtained from such allotments was 290,000, which was a large proportion of the total production of the district. One Indian received $221,000 in royalties; another $165,000; and many got from $1000 to $10,000 apiece.

The Froth-Flotation Process. A contemporaneous event of great importance, just before the World War, was the introduction of the froth-flotation process of ore concentration that had been developed in Australia. In the American zinc industry this was first put into practice by the Butte and Superior Copper Co., operating at Butte, Mont. This enabled the production of a relatively high grade of concentrate from ore that had previously been more or less difficult, and afforded to the smelters a new and large supply of raw material. In 1914 this ore began to come forward in large tonnage. Some metallurgical adjustments had to be made, but they were accomplished with no great difficulty.

Butte and Oklahoma, therefore, about simultaneously offered to the zinc smelters a new supply of ore, more than replacing the waning supply of the older part of the Joplin district and of Colorado.

On the Eve of the War. In 1913, on the eve of the World War, the principal interests engaged in the production of spelter in the United States were the New Jersey Zinc Co., with plants at Palmerton, Pa., Depue, Ill., Iola, Kans., and Collinsville, Okla.; the

American Metal Co., with plants in operation at Bartlesville and Collinsville, Okla., and a large plant in process of construction at Langeloth, Pa.; the American Zinc, Lead and Smelting Co. with plants at Caney and Dearing in Kansas and at Hillsboro, Ill.; the Grasselli Chemical Co. with plants at Clarksburg and Meadowbrook, West Va. The Matthiessen and Hegeler Zinc Co. and the Illinois Zinc Co., two of the pioneers, were operating at Lasalle and Peru, Ill., respectively, rolling most of their product into sheet. The American Smelting and Refining Co. had a small interest in zinc smelting through the United States Zinc Co., a subsidiary, operating at Pueblo, Colo.; and the United States Steel Corporation through a subsidiary, the Edgar Zinc Co., operating at St. Louis, Mo., and Cherryvale, Kans. Besides these there were numerous small concerns. The zinc industry as a whole was quite lacking in integration. The New Jersey Zinc Co., the American Zinc, Lead and Smelting Co., and the Granby Mining and Smelting Co. were substantially the only smelters who operated mines, while the Matthiessen and Hegeler Zinc Co., the Illinois Zinc Co., and the United States Steel Corporation were the only ones who manufactured their product. In the main all of the other smelters purchased their ore supplies in the open market, which was conducted in so far as the Joplin district was concerned on the auction principle, and disposed of their metal product as best they could to some hundreds of galvanizers and brass makers. The producers of ore were counted by hundreds, most of them being individually small, and the industry was quite unorganized, both on the mining and smelting sides, strongly competitive on both sides, and not very profitable as a whole.

Previous to the World War the price for spelter had ranged from 3.5 cents to 7 cents per pound. In 1876, when the market was manipulated by a combination of the Western producers, an average of 7.25 cents was made. In 1894, which was one of our blackest industrial years, the average was about 3.5 cents. At the end of the 19th century about 5 cents was regarded as a normal price for spelter, or a price reasonably to be expected, a safe basis for calculation. When the sheet ground east of Joplin began to show signs of exhaustion and ore of extremely low grade had to be mined, it was considered that there was an economic trend upward and that perhaps a long range average of about 5.5 cents might have to be contemplated.

The War Demands. It was not until the beginning of 1915 that military demand began clearly to develop. One of the first important manifestations was in zinc, and the demonstration in this metal was of singular nature, owing to peculiar conditions.

At this time the greatest single zinc-producing district of the world was Broken Hill, Australia, which was furnishing annually about 500,000 long tons of ore, corresponding with about 200,000 tons of spelter out of a total European production of about 500,000 tons. This great quantity of Australian ore had been almost entirely going to smelters in Belgium and Germany, the enterprise and metallurgical skill of British smelters not having been sufficient to cope with it. The blockade immediately cut off the smelters in Germany, Belgium, and the north of France. The Allies found themselves therefore in the position of having an abundance of raw zinc material but an absence of means for converting it into metal, and the metal was of supreme importance as a constituent of brass, required in immense quantity for cartridge cases.

There arose a scramble to secure such spelter as was available in America. At the beginning of 1915 the market price for common spelter in this country was about 5 cents per pound, and for high-grade spelter about 7½ cents per pound. In the following June common spelter was quoted at 23 cents to 25 cents per pound and high grade at 35 cents to 40 cents. These figures adequately tell the story of scarcity. The market was commanding adventurers to provide additional smelting capacity with the maximum of dispatch, and practically it was only Americans who could do it. The word " adventurers " is properly used, for with uncertainty as to whether the War was going to last a few months or a few years the institution of a new zinc metallurgical enterprise was essentially an adventure.

New Metallurgy. Concerns already in the business began immediately to add more furnaces. For them the undertaking was the simplest. Other parties recalled into use the old coal-fired plants of Pittsburg, Kans., that had been abandoned in 1901. Other parties began the erection of entirely new plants, figuring that they might get their money back in a year and would have to do so in order to be safe. These plants were of course built in the natural gas fields. The United States Steel Corporation, on the other hand, began at Donora in Pennsylvania a very large plant of substantial character which was completed in nine months although about

eighteen would have normally been reckoned for the construction of a plant of that character. The Consolidated Mining and Smelting Co. of Canada and the Anaconda Copper Mining Co. at Great Falls, Mont., each having large supplies of zinc ore incapable of beneficiation by ordinary methods, began the construction of electrolytic plants to employ an old metallurgical process of electrolytic zinc extraction which had previously not come into commercial use owing to its high cost; but under the economic conditions of 1915–16 even a high cost was worth a chance. This was the inception of commercial electrolytic zinc extraction which was subsequently destined to become of major importance in the zinc industry of the world.

Our ore supply was augmented by the importation of Australian concentrate in great tonnages, this movement beginning in the latter part of 1915 and continuing until the early part of 1917. After America entered the World War ships to carry this ore were no longer available and the importation ceased, but two shiploads completing the old contracts were delivered in the early part of 1920. The United States Steel Corporation, at Donora, was the largest user of this Australian ore.

The demand for spelter in 1915 and 1916 was largely for high-grade metal, *i.e.*, 99.9 per cent zinc or higher, it being held that only that kind was suitable for cartridge brass. Consequently there developed a large industry in refining ordinary spelter by re-distilling it. The fact that electrolytic extraction would directly produce high-grade spelter was of course one of the incentives toward trial of that process.

The Zinc Industry Overbuilt. Things moved so fast and furiously in the American zinc industry at this time that within two years producing capacity was practically doubled, rising from about 400,000 tons per annum to about 800,000 tons. The maximum production that was actually made was about 682,000 tons (in 1917). The provision of new capacity was made so swiftly that the boom in the zinc market culminated relatively early, 1915 being the year of climax. Following the middle of that year there were several ups and downs, each rebound being a little weaker than the preceding one, inasmuch as increasing production was showing its effects. At the time America entered the war, in 1917, the glamour had all gone from the zinc market and it was never necessary to fix a price for zinc. On the contrary, zinc producers

were already complaining of the severe competition among themselves and the adversities that they were experiencing in the ways of increasing costs and decreasing efficiencies. Long before the Armistice they were looking forward to their future with gloomy apprehensions and the American Zinc Institute was formed in 1918 in the hope that it might be useful in effecting readjustments. It was even then seen that the industry had become about 100 per cent overbuilt and that there would never be any use for a large part of the then existing smelting capacity. It began to be perceived that the War had not been so profitable a thing for the industry as many had thought. Some persons who sold out early and stayed out did well. Other persons who bought in and stayed in experienced the opposite. The Granby Mining and Smelting Co. sold out early for an immense price. The American Zinc, Lead and Smelting Co., which had won the fortune of a Monte Cristo, used it for expansion and lost most of it. The rank and file of producers made big profits on the advance and lost them on the decline and ended worse than at the beginning, owing to the disastrous conditions created in the industry. At no time since the end of the War has the zinc industry as a whole been steadily and generally profitable. The New Jersey Zinc Co., with its special and diverse interests, however, has always been an exception.

Comparative Economics. This is an appropriate place for a review of the broad economics of the competitive Western zinc industry, based especially on the Joplin district. In that district the standard grade of concentrated ore has always been 60 per cent zinc. During the nineties such ore used to sell for about $25 per ton at the mines. Since 1901 the trend of price has been generally upward, owing to the exigency of having to mine and mill more tons of ore in order to get one ton of concentrate. Since 1915 advancing terms for labor and material contributed further to this trend, and in recent years the price has been about $45 to 50. On the other hand, an offsetting condition to increased cost of labor, etc., has been improvement in mining and milling practice, especially the latter. Previous to 1901 the milling practice was very slovenly. Not more than 50 to 60 per cent of the zinc in the ore was recovered as concentrate, nearer the lower figure than the higher. By 1904 improvement had been made but the average extraction of mineral in the district was probably less than 65 per cent. In 1906 the introduction of regrinding machinery and slime tables

had increased it to somewhere between 65 and 75 per cent in the better mills. At the present time, with the help of the flotation process, it is probably in the neighborhood of 85 per cent.

Similarly as to the smelting practice. In 1899 the extraction of the best-managed works was about 82 per cent of the zinc, after roasting. What it was in former times no one knows. The cost of smelting was about $10 to $12 per ton of ore and probably had been in the neighborhood of those figures for twenty years previously. Run of mine coal cost $1 to $1.50 per ton; slack about 50 cents.

The inauguration of smelting with natural gas reduced the smelting cost to about $7 per ton of ore. With improvement in practice extraction of metal rose to 85–86 per cent. In 1914 the cost of smelting was in the neighborhood of $10 per ton of ore. An average labor requirement was 2¼ man-days per ton of ore.

Disastrous Effects of the War. The War had a disastrous effect, the efficiency of labor becoming impaired while its wage increased. In 1920 an average labor requirement was 2.5 man-days per ton of ore, while the average daily wage had been multiplied by 2 to 2.67. The average extraction of zinc in smelting decreased from 1914 to 1920 at least two points, and maybe three, meaning a reduction from 86 to 84 or 83 per cent. The cost of smelting was at outrageous figures, anywhere from $22 to $25 per ton, or even more.

Since 1920 there had been marked improvements as the result of strenuous efforts on the part of management. Extraction has been raised from 86 to 90 per cent, and while there have been no reductions in rate of wages, there have been economies in the use of labor and fuel, so that cost of smelting has been reduced to a figure below $20 per ton. Post-War costs, however, are still higher with respect of pre-War costs than is post-War price for spelter in comparison with pre-War. It is necessary, therefore, for zinc distillers, confronted by increase in competition from electrolytic extractors, to strive earnestly for further improvement.

Since the Armistice there have been few corporate changes in the American zinc industry. Many of the weaker concerns that sprang up during the War retired. The smelting industry was then left in the hands of a group of concerns of substantially equal strength, no one of which is sufficiently large to acquire a dominating position. The most important instance of growth has been

that of the Anaconda Copper Mining Co., producing electrolytic spelter, which in 1926 accomplished an output of 112,000 tons, about 17 per cent of the American total.

Metallurgical Groups. The American zinc distilling plants are grouped as Eastern and Western, the former being arbitrarily defined as those which are east of the Mississippi River, and the latter west. All of the Western plants smelt with natural gas. Of the Eastern plants two use natural gas and the others use coal. The scale of operation of these plants as of July 1, 1926, was as follows:

Group	No. of Plants	No. of Retorts	Capac. of Retorts, Cu. Ft.	No. of Retorts in Use	Per Cent of Retorts in Use	Per Cent of Cu. Ft. in Use
East .	12	71,908	116,433	45,040	62.64	62.74
West .	11	46,344	78,442	35,296	76.16	75.67
Total .	23	118,252	194,875	80,336	67.94	67.95

There were also eight plants idle, with a total of 28,024 retorts. Of the plants that were active at this time, the Eastern, if operated at full capacity, would require of roasted blende or calamine 2090 tons a day, and would produce 1150 tons of zinc. The Western plants would require 1370 tons of ore and would produce 763 tons of zinc. Together they would need 3460 tons of ore and would produce 1913 tons of zinc. An average operation of 360 days a year would require about 1,250,000 tons of ore and would produce about 690,000 tons of zinc. The requirement of raw ore would be considerably larger, inasmuch as the furnace charge has experienced a loss of weight in roasting blende, which is by far the major source of supply. Anaconda's capacity for producing electrolytic zinc at this time was about 120,000 tons. The total capacity of active plants in the United States was therefore 810,000 tons for the annual production of spelter.

Enumeration of the number of retorts in existence and in use does not in itself afford a conclusive figure of percentage. If density of charging be the same, the larger retort obviously takes more ore than the smaller. There are coördinating technical factors to be taken into consideration, but on the whole the percentage of cubic feet of retort volume is a truer index than the percentage of number of retorts. On July 1, 1926, the percentage

of capacity in use on the basis of volume was about 68. This would indicate the making of distilled zinc at the rate of about 40,000 tons per month. Electrolytic zinc being then produced at the rate of about 10,000 tons per month, the total would be about 50,000 tons, which is substantially the recent and present rate of production.

The American zinc metallurgical industry is now divided into several branches, besides geographical, which are more or less distinct. The New Jersey Zinc Co. produces from its Franklin and Stirling ore a high grade of spelter commanding a premium over all other, which is used largely for special purposes such as die casting, the manufacture of French oxide, and soft sheet zinc. Anaconda produces electrolytic spelter which realizes a premium (at present about $\frac{5}{8}$¢ per pound) over ordinary spelter and has acquired a commanding position in the brass industry. The Matthiessen and Hegeler Zinc Co. and Illinois Zinc Co. are the leading figures in the rolling of sheet zinc, and their production of spelter goes mainly into that manufacture. The ordinary brands of spelter that are produced by the rest of the smelters, from Joplin and Western ores, go most largely into the galvanizing industry; brass-makers and sheet-rollers taking the remainder.

Selective Flotation. A post-War event of great consequence was the introduction in 1921 of the process of selective flotation, which made possible the beneficiation of ores that are complex cryptocrystalline mixtures of the sulfides of lead, iron, and zinc, that up to this time had remained more or less refractory. This was of great importance to both distillers and electrolytic extractors, for each of whom a high grade of ore is advantageous. The new process of selective flotation obtained widespread application in 1925–26 and had a powerful effect upon the zinc market of the world, almost overnight altering the condition of scarcity of ore supply into a state of plethora.

Industrial Uses of Zinc. The industrial use of zinc in the United States, according to the American Bureau of Metal Statistics, is given in the table on the opposite page, which refers only to the use of zinc in the form of spelter.

In addition to the uses given in the table there is in the United States a small use of zinc in the form of metallic powder, and a large use in the forms of zinc oxide and lithopone, both of which are made directly from ore.

ESTIMATED INDUSTRIAL USE OF ZINC IN THE UNITED STATES

(In tons of 2000 lbs.)

Purpose	1910	1916	1917	1919	1920	1921	1922	1923	1924	1925
Galvanizing (total)	162,000	200,000	190,000	163,000	192,000	138,100	205,400	235,200	240,000	286,600
Sheets				81,500	99,800	72,500	110,800	121,300	122,900	141,600
Tubes				27,900	34,000	28,200	44,100	49,000	50,300	61,100
Wire	[b]	[b]	[b]	33,900	35,900	19,500	25,000	32,700	29,000	35,700
Wire cloth				4,300	4,800	3,800	6,100	6,100	7,100	6,800
Shapes [a]				15,400	17,500	14,100	19,400	26,100	30,700	41,400
Brass Making	54,000	175,000	170,000	155,000	144,000	75,000	145,000	175,000	155,000	165,000
Sheet Zinc	29,700	47,500	57,000	55,000	53,200	30,400	53,500	55,800	61,000	71,100
Other Purposes [c]	24,300	27,800	28,000	29,000	35,000	19,000	36,000	49,000	56,000	60,000
Totals [d]	**270,000**	**450,000**	**445,000**	**402,000**	**424,200**	**262,500**	**439,900**	**515,000**	**512,000**	**582,700**

[a] Includes pole-line hardware, hollow ware, chains, and all articles not elsewhere mentioned. The estimates for the use of spelter under this head, and also for wire cloth, are probably incomplete. The enumeration for 1924 includes figures from consumers not previously accounted for.

[b] Not separately reported.

[c] Includes spelter used for the manufacture of French oxide, lithopone, atomized zinc dust, die castings, slush castings, and for the desilverization of lead.

[d] Probably a slight overstatement, ascribable wholly to overestimation of the use of zinc for brass making.

Zinc oxide is employed very extensively in the rubber industry, and also as a white pigment. Lithopone, which is an artificial compound of barium sulfate and zinc sulfide has become one of the most important of pigments. In recent years zinc oxide and lithopone have made great headway in the pigment trade at the expense of white lead.

The world's production of spelter in 1926 attained a total of 1,373,000 short tons, whereof the production in the United States was about 639,000 tons. This falls short of measuring the relative magnitude of the American zinc industry, however, in that our production in 1926 in the forms of oxide and lithopone made from ore was in the neighborhood of 150,000 tons. In America both of these substances are made directly from ore, whereas in other countries they are made chiefly from spelter. The total production of zinc oxide and lithopone was of course much larger than this estimate, which eliminates the manufacture from spelter and zinc scrap and by-products.

High-Grade Zinc. A noteworthy development in the zinc industry since the War has been the rapidly increasing use of high-grade zinc. High-grade zinc, which is about 99.5 per cent fine, has great superiority in softness and in other qualities over common spelter, which is generally only about 98.5 per cent pure, and is especially desired in the manufacture of the better grades of brass. High-grade zinc also finds increasing application in the manufacture of die castings, a rapidly growing industry. Out of the world's production of 1,373,000 short tons of spelter in 1926 about 275,000 tons was what may be most severely defined as high grade, whereof about 235,000 tons were electrolytic. Of the American production of spelter in 1926 nearly 25 per cent was of the high-grade class. Previous to the World War not much attention was paid to this classification, high-grade spelter being made only in limited quantity. Consuming manufacturers have learned to discriminate, and whereas formerly they bought simply spelter now they purchase it on specifications best suited to their purposes. Thus during the last 10 years the American zinc industry, both in production and consumption, has come under the control of science.

In the zinc industry of the United States, the subject of labor has been destitute of striking features. The zinc mining and smelting districts have been remarkably free from strikes and disturbances. The only seriously embarrassing factor in this

particular in the early days was the strikes in the coal mines of Kansas, which frequently cut off the fuel supply of the smelters and thereby checked spelter production and created market disturbances. The transfer of the smelting industry to the natural-gas field eliminated this source of trouble. Both in the mining and smelting districts the conditions of living have been favorable.

Neither the miners nor smelters have consented to be unionized. In the Joplin district the small scale of operations afforded to every miner the opportunity to become a producer on his own account, and the idea of restriction of effort was never welcomed. This spirit still prevails to a large extent.

In the smelting districts the conditions conform to the peculiarity of the art of zinc smelting, whose process is not continuous, but rather moves in a 24-hour cycle. The major part of the daily work is concentrated in what is called the " maneuver," occupying from three to five hours early in the morning. An average of four hours, beginning at 5 A.M. and ending at 9 P.M., is common. The men engaged in this are paid different rates according to their special function and the degree of skill required. Upon completion of the maneuver the bulk of the plant personnel goes home. A few men have to remain with the furnaces. Formerly these worked twelve-hour shifts; now only eight hours.

The miners in the Tri-state district are mostly of American ancestry; likewise the smelters. In the Eastern smelting districts there has gradually been an influx of workers of foreign descent; first, Slavs, later, Spaniards. At the present time plant personnel is likely to be divided among Americans, Slavs, and Spaniards. The smelters of foreign origin often have come from zinc-smelting districts in Europe.

In wages and hours of work the zinc industry has experienced the advances and reductions, respectively, that have occurred in other industries. Illustrative of the increase in wages in southwestern Missouri are the following data from the records of the Granby Mining and Smelting Co.: Previous to 1893 the wages paid to miners at Granby were $0.75 to $1.25 per day; from 1895 to 1898, they were $1.25 to $1.75; in 1899–1903 they had risen to $1.75 to $2; and in 1903–1906, to $2 to $2.50. The difference in the wages of miners and common labor in the Joplin district was rather uniformly 50 cents per day. The working day was 10 hours.

During the last twenty years the scale of wages was generally

advancing. The day of work was reduced to eight hours. The economic effect of the War was to enhance the rising scale. At the end of the War the wage rate in Oklahoma was about \$4.25 per day for machine men and \$3.75 for helpers, which was about \$1.50 per day higher than at the beginning of the War. During the depression of 1921 a reduction of \$1 per day was made, but this was subsequently restored and at present the rate for miners is about \$4.50 per day.

As for the smelters the average plant rate at the beginning of the twentieth century was about \$2 per day. From that figure there was not much change up to the beginning of the War. At that time the average was about \$2.20. During the War the demand for smelting labor was so strong that the average daily wage became multiplied by 2 to 2.67, varying according to districts. Since the War there have been reductions and readjustments, but on the whole the terms have continued high. In 1924 the average for all labor in an Oklahoma plant was \$4.62 and in an Eastern plant \$5.25 per day. These high rates for labor have been in conformity with supply and demand. Their effect upon the attitude of smelting labor has not been wholly agreeable to management, which has found it more difficult to maintain discipline and consequently is likely to suffer from carelessness in work.

The Corporate Position. Zinc production in the United States is only a partially integrated industry. The New Jersey Zinc Co. is the only one that mines, mills, smelts, and manufactures. The Anaconda Copper Mining Co. might also do that, but for the present prefers to buy its raw material from other producers, holding its own mines in reserve. The other interests in the zinc industry combine mining and smelting or smelting and manufacturing to some extent, but in general mining, smelting, and manufacturing are done by different groups, whose commercial interests are more or less in conflict.

A noteworthy feature of the zinc metallurgical industry is that to a large extent it is carried on as a subordinate enterprise by great corporations whose major activities are in other fields. Their zinc smelteries are major units in the zinc business, but nevertheless are mere appendages to greater business. In many respects this is unfortunate for the zinc business, tending as it does to prevent broad economic coöperation.

Reviewing this situation, we may remark that the major part

of the zinc smelting in the United States is done by the U. S. Steel Corporation, the Anaconda Copper Mining Co., the Eagle Picher Lead Co. (whose chief interest is in the white lead business), the Grasselli Chemical Co. (whose chief interest is in the general chemical business), the American Metal Co., and the American Smelting and Refining Co. (both of which are general mining and metallurgical concerns, with interests in copper and lead superior to that in zinc). It would therefore be futile to review the financial history of these companies from a standpoint in the zinc industry alone.

The only big corporation, fully integrated, in the zinc industry is the New Jersey Zinc Co. By virtue of its possession of two phenomenal mines, its ability to produce the highest grade of spelter in the world, and its predominance in the zinc oxide business, this company has been the most brilliantly successful in the history of zinc. Its record is not to be taken as a criterion for any of the others. In 1897, following the consolidation, the capitalization of this company was made $10,000,000, at which figure it remained until 1915. Dividends were paid at a gradually increasing rate: 5 per cent in 1898, 12 per cent in 1901, 16 per cent in 1902, 18 per cent in 1904, 30 per cent in 1910, and 50 per cent in 1912. In July, 1915, the accumulated surplus was capitalized by the declaration of a 250 per cent stock dividend, thereby increasing the amount of stock outstanding to $35,000,000. In May, 1920, the authorized capital stock was increased to $50,000,000. Of the increased stock $7,000,000 was paid as a 20 per cent stock dividend and at the same time stockholders were allowed to subscribe at $100 per share to $7,000,000 of the new stock in the ratio of one share of new for each five shares of old. The remaining $1,000,000 of the increased capital stock was reserved for offer to the employees of the company on terms to be fixed by the directors. In 1922 the dividend on the new capitalization was 8 per cent. Since then it has been in general 8 per cent regular and 4 per cent extra.

APPENDIX

NON-FERROUS METAL STATISTICS

By W. R. Ingalls[1]

Previous to the War, statistical work in the non-ferrous metals, especially copper, lead, zinc, tin, and the precious metals, was unorganized and of infrequent publication. The United States Geological Survey had done excellent work in respect of the domestic copper, lead, and zinc industries; similarly, the Bureau of the Mint in respect of gold and silver. Their investigations were limited, however, to annual reporting, and though the Mint was always prompt, the United States Geological Survey was dilatory. Such statistical research, although of immense importance in keeping up a record of progress, was of no value for commercial guidance.

In recognition of this, R. P. Rothwell during the eighties had begun to direct the Engineering and Mining Journal, of which he was then the editor, to this work, and with the issuance of an annual statistical number had won the approval, coöperation, and praise of the producers in the several major industries. This led Rothwell to the institution of "The Mineral Industry" as a statistical, industrial, and technical review. I was associated with Rothwell at that time and had the duty and honor of formulating and executing the plans for the first volume of "The Mineral Industry," which is not, however, to appropriate any credit belonging to Rothwell, for the idea and inspiration were wholly his.

I may here pause long enough to say that the American metal industries owe more to Rothwell than is now appreciated. He was the earliest exponent of the advantage of the principle of transparency in industry, statistical, technical, and in all ways. With the coöperation of Dr. James Douglas he eradicated old traditions of the desirability of secrecy in plant operations. They

[1] Director, American Bureau of Metal Statistics.

worked unremittingly for the opening of doors, the exchange of information through visits of technical men among themselves, the development of technical literature, and the institution of statistical information. I am sure that the great development of American industry, and the reason why we are now so far ahead of the Europeans, is ascribable to the sowing and germinating of such seeds in the late eighties and early nineties of the last century. While Rothwell and his colleagues were doing this in the metal industries, others were acting likewise in other industries.

Among the Europeans the Germans conducted themselves more on our lines than anybody else. Indeed, I am not sure that in the non-ferrous metals the Germans were not the first to appreciate the immense value of prompt statistical information. Indeed, I know that Rothwell was influenced by German thought in this respect, but Rothwell approached the subject with a broader vision and thought in terms of principle rather than of policy. Anyway, the Metallgesellschaft of Frankfurt am Main at an early date instituted international statistical investigation and published a summarizing yearbook. The data that was thus accumulated in its headquarters was of course of great value to itself. The commercial success of the Metallgesellschaft became the subject for more or less jealousy among American producers, who were prone to accuse it and its affiliated interests of sharp and brutal practices. It is rather to be believed that if these German interests forged ahead of their competitors in trade, the reason was due to their superior knowledge of economic situations. Progress in human affairs is always slow and generally occurs through cautious steps rather than by leaps and jumps. American producers were much slower in learning the advantage of transparency in industry in the economic sense than they were in the technical.

When, in 1905, I became the editor of the Engineering and Mining Journal, following an interim administration after the death of Rothwell in 1901, I was, from previous association with him, saturated with his ideas; and proceeded to give to the publication a strong economic and statistical flavor, which continued throughout my editorship. In the course of time we instituted a reporting of the monthly production of crude copper, doing as well as we could. In so far as concerned the reporting by companies smelting their own ore, the problem was relatively simple, but accounting for copper smelting on a custom basis was difficult, and although

the late Edward Brush, of the American Smelting and Refining Co., gave us his important coöperation we were unable to handle that phase of the subject satisfactorily; in fact, that could not be done until many years later when the American Bureau of Metal Statistics had become a well-organized affair. It is for this reason that the later statistics of the American Bureau of Metal Statistics and the earlier statistics of the Engineering and Mining Journal, touching copper production by months, do not exactly match.

In the meanwhile the sellers of primary copper organized the Copper Producers Association, about 1910, which began the monthly reporting of production, deliveries (domestic and foreign), and stock on hand by the refiners. Representatives of the refiners met once a month, at which time the figures were communicated, being given immediately afterward to the newspapers. This compilation was inspired by a view of immediate market position and behavior rather than with a broader economic perspective. It developed soon, however, that the stock market was more concerned than the commodity market, and it was not long before the resulting situation became disagreeable. Important producers became desirous of abandoning the system, but were reluctant to initiate what looked like a step backward. The opportunity came naturally, however, with the advent of the War, and when in August, 1914, what was practically a moratorium had to be created in the copper market, the Copper Producers Association and its monthly statistics faded away without attracting any attention.

In the course of the War on several occasions there were darkness, confusion, and uncertainty in the copper industry, when it was clear that statistical revelation was necessary for the throwing of light. On such occasions the Engineering and Mining Journal came forward, and with the coöperation of the producers, made the necessary statistical collections. These were, however, irregular. At the same time the War Industries Board, in Washington, found it necessary for the allocation of copper, lead, zinc, and other commodities to study quantitatively their industrial uses. In this work the War Industries Board was assisted by committees representing separately the copper, lead, and zinc producers, the same thing naturally being in process in almost all of the other industries.

This was paving the way for the general economic and statistical development that has occurred in the United States since the War. The components of the several industries had during the War

grasped the thought, had become accustomed to practicalization thereof, and had become able to visualize the importance of the development not only in war time but in peace time. It seems to me that this appreciation and the creation of a state of mind favorable to industrial organization and economic coöperation was the one great thing, indeed the only thing of value, that America got out of the War. It may be worth to us more than the enormous cost of the War to us.

Early in 1919 the leading factors in copper, lead, and zinc production began to consider the need for thorough statistics of those industries, believing that New York as the center of the copper industry of the world ought to take the leadership, and that we could here, if we wanted to, make statistical achievements far beyond anything that had been accomplished in the past. For this purpose the American Bureau of Metal Statistics was formed late in the spring of 1920. It began to function that midyear, making its first statistical investigations retrospective to the beginning of 1920.

The organization of the Bureau was quite informal and has remained so. There has been no constitution or by-laws, but an unwritten constitution developed out of experience and agreement. It was agreed in the first instance that expense should be prorated according to production. Privilege of membership is open to all producers of refined metals. A new producer may automatically acquire membership upon acceptance of prorating of expense. Government of the Bureau rests with an advisory committee and an executive committee, both of these committees being permanent in their personnel. All actions of both committees are by common consent, *i.e.*, unanimous.

For several years following the organization of the Bureau its monthly statistical reports were made confidentially to its members, although its annual report was from the outset published in the form of a yearbook for general circulation. In 1924, in deference to a widespread wish, the policy of publicity in all respects was adopted. Inasmuch, however, as this was bound to increase the expense it was deemed proper to make a nominal charge to non-members desiring to avail themselves of the privilege, for the service of the Bureau. There thus arose a class of subscribers. In adopting this new policy the Advisory Committee of the Bureau laid down the principle that all reports of the Bureau should be

made available to the public, *i.e.*, to subscribers, with the same fullness and at the same time as to members.

The advisory committee of the Bureau holds meetings at irregular intervals, in some years four times, in other years only once or twice. These meetings are called by the chairman of the executive committee only when there is some business to be discussed, especially pertaining to the administration of the Bureau. The Bureau is in no way a trade organization, and industrial or commercial considerations do not arise either in its office or in its meetings. Its scope is purely informational and statistical. The original conception was that it should be institutional, international, and scientific.

Copper production of North and South America is reported monthly in three ways, viz.: as made by the mines, by the smelters who beneficiate their product, and by the refiners who treat the crude product coming from the smelters. Stocks are reported in all positions between the smelters and refiners, including what is in transit. Shipments from the refiners are reported as domestic and foreign, the latter being given according to countries of destination. The shipments of refined copper are further classified as to shapes, *i.e.*, ingots, wire bars, cakes, billets, etc. This report, giving a complete picture of the metal from the mines to the exit gateway of the refiners, is made about the twelfth day following each month. About the twentieth day following each month a report is made of the world's production of copper to the extent of 98 per cent, by countries, this being accomplished by cable and being made possible by the coöperation of the producers in foreign countries.

The reporting of lead statistics, covering the United States and Mexico, is done with the same detail and substantially the same promptness as in the instance of copper. The world's production of lead is reported to the extent of 85 per cent.

The statistics of the zinc industry are not reported with the same detail as copper and lead. The American Zinc Institute collects the domestic statistics of production and price, while the American Bureau of Metal Statistics collects the production statistics of foreign countries and makes a monthly report of the world's total, to the extent of 97 per cent, by countries.

The Bureau collects and reports monthly the statistics of silver production of the world, to the extent of 89 per cent, and also reports as to stocks in some of the countries.

The Bureau further reports the metallurgical production of arsenic in the United States and gives attention to antimony and tin, which metals are chiefly imported.

In respect of copper, lead, zinc, and silver the Bureau summarizes imports and exports as to all of the important countries of the world. Such data must necessarily be collected by the respective governments in the first instance. A coöperation has been established, however, wherein the Bureau is able to give expert advice, especially in Washington. This is highly appreciated.

An important work of the Bureau has been the study of the consumption of copper, lead, and zinc in the United States according to industries. In this it has won the coöperation of most of the important manufacturers and consumers, who report annually the quantities of the metals that they fabricate or use. Take automobile manufacturers, for example: there is reported fabrication in the final form, *i.e.*, the automobile; while in the instance of the electrical industry there is a report by light and power companies of final use. This study is so intricate and laborious that it cannot be done more frequently than annually; although it is possible that it may eventually pass to a quarterly, or even a monthly, basis in respect to some of the major branches of manufacture. It is important for many reasons to be informed both as to the industrial and geographical use of the metals. In no other country of the world has any investigation of this important subject been undertaken. For that matter, not even as to production and stocks is any other country of the world statistically so far advanced as America.

The American Bureau of Metal Statistics publishes annually a statistical book of about 108 large pages, summarizing all of the important statistics concerning non-ferrous metals. An edition of 2500 of this book is printed, copies of which fall into the hands of substantially everybody who is commercially and technically engaged in these industries all over the world; and a liberal distribution of them is made among governmental bureaus and public libraries.

Besides the statistics before mentioned, the Bureau makes annual reports as to producing capacity, and makes special studies of subjects of concern to the respective industries. Such studies are purely statistical, and their results are presented as the ascertainment of facts, no economic comment or interpretation

being offered. Fact, not opinion, is indeed the guiding principle of the Bureau, and has always been so. Even with the great facilities that the Bureau enjoys, including the earnest coöperation of producers all over the world, the ascertainment of fact is not always easy and not even are the most expert researches infallible. It is another cardinal principle of the Bureau that when an error has been made and has become known it should be corrected, the objective being establishment of truth. Out of this consideration revisions of the statistics given in the year-book are constantly made, attention being drawn to this in the preface, with the advice that reference should always be made to the latest figures.

Immediately after the War it was very difficult to re-open channels of communication with many foreign countries, and it was consequently very difficult to fill in statistical gaps that had occurred. Much effort was required, and information first obtained was often imperfect; much investigation was necessary and many revisions of tentative data had to be made. As the War passed more and more into the background, however, these difficulties gradually disappeared. There has been another difficulty, for in many instances foreign countries did not themselves possess needful data, wherefore it has been necessary to develop the coöperation of producers in those countries. This has every year become easier with the growing recognition of the Bureau as an organization of international scope and usefulness.

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